

PLAY BASED EXPLORATION

A GUIDE FOR AAPG'S IMPERIAL
BARREL AWARD PARTICIPANTS

Provided by Royal Dutch Shell



Shell Exploration & Production

GOOD GEOLOGY VERSUS SOUND BUSINESS DECISIONS

WEST GREENLAND

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INTRODUCTION

Play Based Exploration, or PBE, is a phrase that is being heard more and more frequently as Explorers return to their geological roots in the increasingly demanding search for exploration opportunities, in particular those which offer the potential to add material hydrocarbon volumes to our portfolio.

Many of you will have encountered the concepts of Play-Based Exploration during training. For you, this booklet is intended as reminder of the essentials of PBE. For those who have not yet experienced the training, this is an introduction to the concepts, and we hope will encourage you to find out more details from your technical advisors.

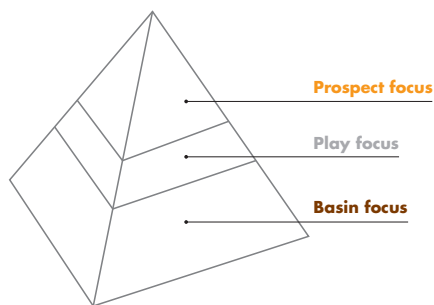
What exactly is Play Based Exploration? It is simply a method to build and leverage an understanding of the basins and petroleum systems in which we work, and the geological plays they contain. The benefits lie in providing better early **Focus** to a range of exploration activities.

Efficiency improvement also results from having a better focus on our most valuable plays. The whole approach provides greater technical rigour, and hence quicker, more confident decisions, even with partial or incomplete data. New play **Growth** is enabled by the creativity and innovation that can be unleashed most effectively at the level of basin or petroleum system understanding.

The PBE methodology is encapsulated in the "Exploration Pyramid", where the initial focus is on the basics - the determination and description of the regional context and the basin framework leading to an understanding of the working petroleum system(s).

Petroleum system understanding forms the basis for the subsequent play focus - quantifying the various aspects of the system within each play, and using tools such as common risk segment mapping to highlight sweet spots within each play.

When the plays have been mapped and where possible, quantified, then the focus shifts again to use more detailed geological and geophysical analysis to define prospects within each play, and



build the portfolio, including making estimates of volumetrics, risk and uncertainty.

PBE, admittedly, requires up front investment of time if the regional play framework has not already been defined. However, that investment will be repaid by swifter and simpler assessment of individual prospects, and in the quality of subsequent decisions.

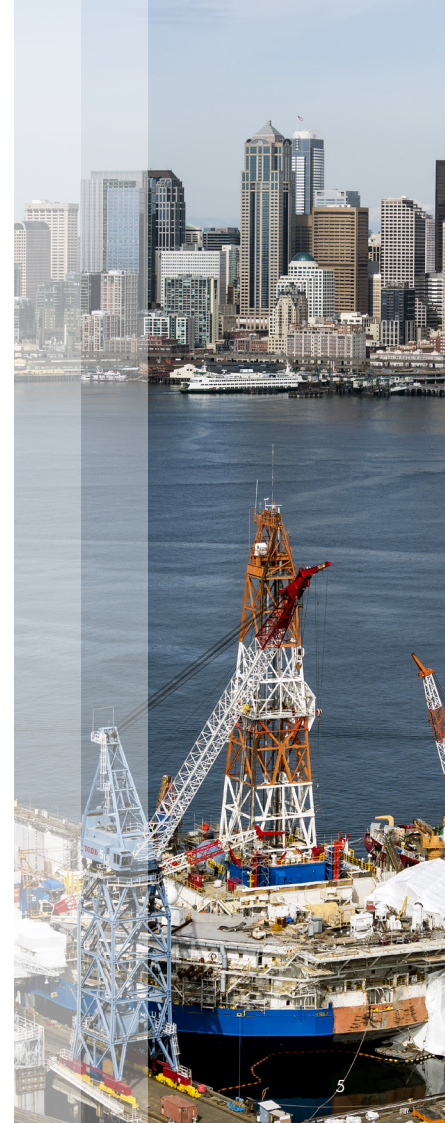
Using a play-based approach, or regional understanding, is not new to Shell. However, in the 1990s, particularly when the oil price was low, an asset focus characterised exploration, with near-field opportunities to add value fast being given priority over more 'wildcat' type exploration. This filled the needs of the times, but could not be sustained in terms of consistently adding volumes to our portfolio.

With the need now to add more material exploration opportunities, we are rediscovering the regional approach to geology which had been somewhat neglected in the detailed evaluation of individual blocks and prospects.

Our new ventures team has successfully added

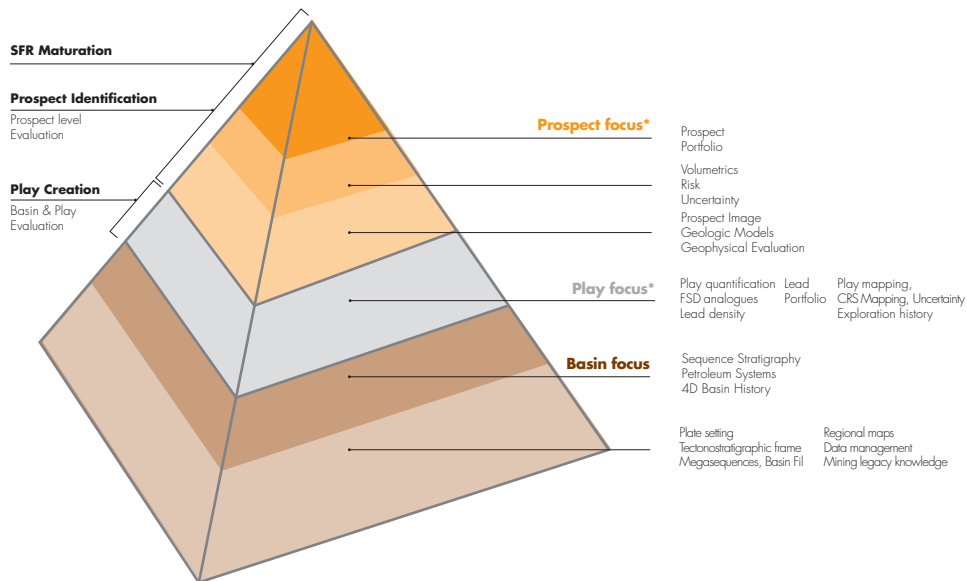
significant acreage in recent years using essentially a play-based approach, and much of this growth is in areas new to Shell. Play Based Exploration will also be essential in the fast and effective evaluation of these ventures. It will also play a vital role in evaluating new plays in our existing areas.

The most important effort to improve exploration performance is, by far, the rebuilding of a play-based approach to exploration. This can quickly lead to more opportunity identification through better understanding of petroleum systems, more coveted prospects on competitor acreage, better risking, better POS polarisation, and more efficient exploration campaigns.



Chapter I

THE PLAY BASED EXPLORATION PYRAMID



The fundamental elements or building blocks of the PBE methodology are represented by the PBE Pyramid. It is organised into levels of Basin, Play and Prospect focus with appropriate key inputs and activities identified.

Basin Focus

The essential ingredients for the petroleum system are verified by examining the basin as a whole. Elements such as the plate setting, tectonostratigraphic framework and basin history determine the fill, stratigraphic sequences and potential for generating and trapping hydrocarbons.

Play focus

An understanding of the petroleum system in the basin leads to the identification, mapping and quantification of plays within the basin. Existing knowledge is summarised in play element, summary play maps, and common risk segment maps, leading to the identification of sweet spots.

Prospect focus

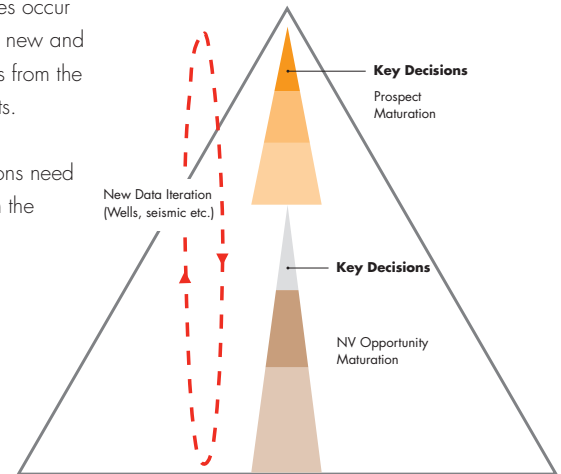
Most play execution activity is concerned with defining prospects - seismic evaluation and other maturation activities, and eventually drilling

selected prospects from a portfolio. A geological model is built and then volumetrics, technical risk and confidence assessed for a range of models and prospects.

New Venture opportunity evaluation usually occurs at the lower part of the pyramid (basin-to-play focus levels). Decisions are typically made about selecting the right basin, the right play and then the best acreage (sweet spots) for investment.

Detailed prospect level evaluation activities occur in the upper part of the pyramid both for new and existing ventures, turning geological leads from the play inventory into firm, drillable prospects.

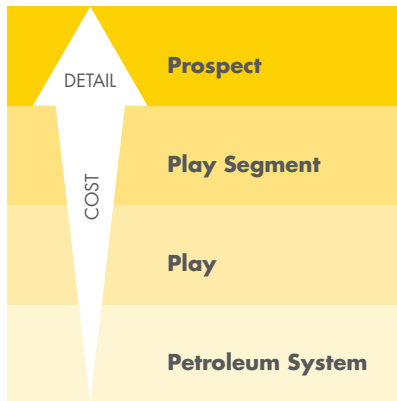
To be done well, these prospect evaluations need to be carried out with a firm grounding in the play context.



THE FOUNDATION OF A GOOD PROSPECT INVENTORY

The pyramid shows the importance of the foundations - the solid understanding of the basins and plays needed to build a good prospect inventory and select the best of these for drilling. An inventory built upon an incomplete understanding at the play or petroleum system will not be optimal. Play-based exploration can be seen as having

quality assurance “tollgates” at the conclusion of each of the basin and play focus levels that allow us to proceed with confidence to the next level of evaluation. Our understanding at each of the levels is not static - there is an iterative feedback loop that takes new information from drilling, studies etc. back to the appropriate level to update the totality of knowledge.



Petroleum Systems, Plays and Prospects

Prospect - a potential trap, a successful prospect turns into an oil/gas field when drilled or disappears when it is unsuccessful. Many can exist in one play.

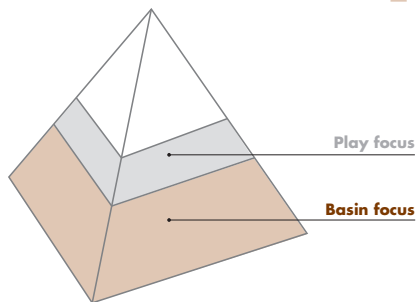
Play Segment - subdivision of a geologic play. Fields and prospects that share common geological controls and thus a common “PoS” profile.

Play - a group of hydrocarbon fields and prospects having a chance for charge, reservoir, and trap and belonging to a geologically related stratigraphic unit (eg - the Upper Jurassic play).

Petroleum System - a natural system that links an active or once active source rock to all of the geologic elements and processes that are essential for a hydrocarbon accumulation to exist in time and space regardless of economics.

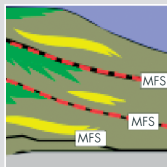
KEY WORKFLOWS

These are the key workflows that together form the Basin and Play level Focus



Play Focus Workflow

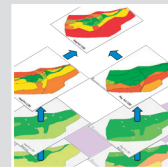
A Play Definition (page 20)



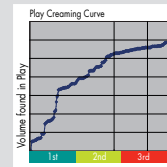
B What we know, where we know it - Play Element and Play Summary Mapping (page 24)



C Common Risk Segment Mapping (page 28)



D Quantitative Assessment (page 52)

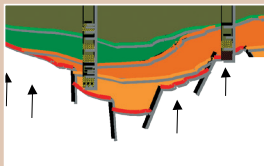


Basin Focus Workflow

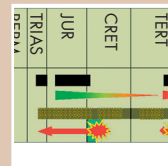
1 Basin characterisation (page 24)

2 Tectonostratigraphic framework (page 24)

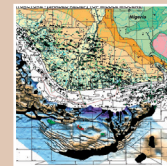
3 Sequence analysis (page 24)



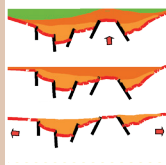
6 Assess petroleum system (page 14)



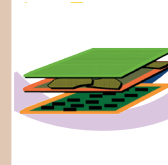
7 Trap distribution (page 16)



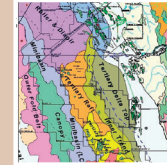
4 Basin evolution (page 13)



5 Source rock, reservoir, seal distribution (page 13)



8 Identify plays (page 17)

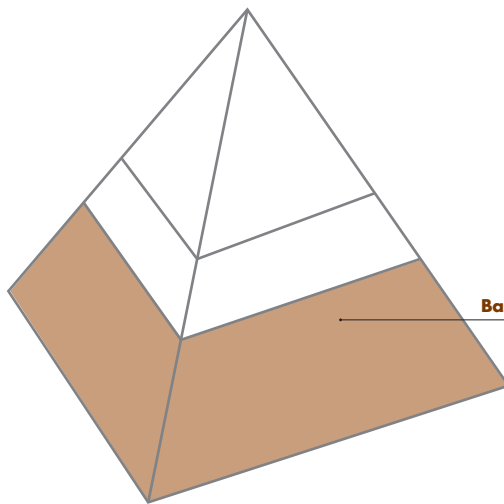


Chapter II

BASIN FOCUS: "THE FOUNDATION"

The basis of Play-Based Exploration

- Basin type, fill and structural evolution are the **critical elements** that build and combine to define a working Petroleum System.
- **Geologic boundaries are defined** that later translate to the natural boundaries for the reservoir, entrapment and charge play elements.
- Determine the **hydrocarbon generation, flux, and timing**.
- Together, these elements define the **hydrocarbon potential** for the basin.



Basin focus

Sequence Stratigraphy
Petroleum Systems
4D Basin History

Plate setting
Tectonostratigraphic frame
Megasequences, Basin Fill

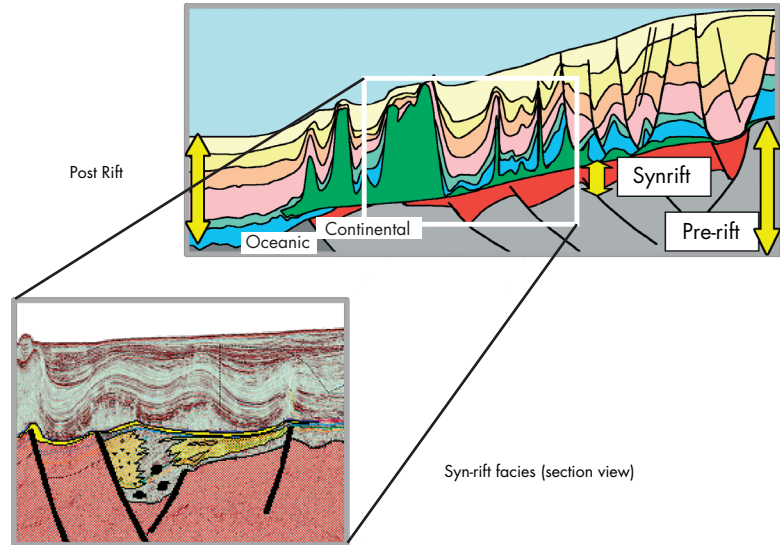
Regional maps
Data management
Mining legacy knowledge

STEPS 1-3

Basin characterisation, tectonostratigraphic framework and sequence analysis

The tectonic setting(s) of a basin is a primary control on structural architecture, stratigraphic fill, source rock distribution, thermal history, and the foundation for understanding petroleum systems, plays and ultimately, prospectivity. All that follows in play-based exploration builds upon this foundation. Early identification of **Megasequences** is an essential part of the basin-fill analysis.

Megasequence: A group of related depositional sequences, bounded by major regional unconformities, created in response to large-scale processes such as plate tectonics and eustacy. Influenced to a lesser degree by depositional rates. Examples: of megasequences are 'Syn-Rift', 'Passive Margin'. (A basin fill will typically contain several distinct megasequences.)



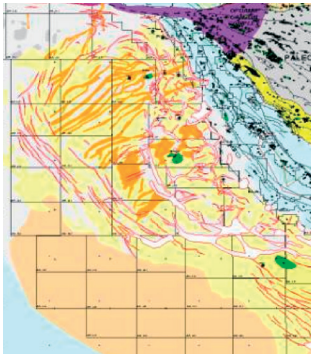
STEP 4-5

Basin evolution, source rock, reservoir and seal distribution

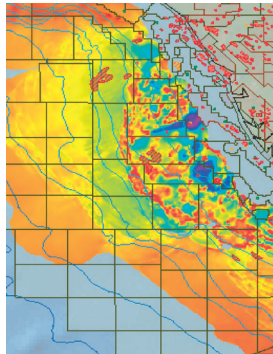
Determining the basin evolution is essential to understanding the basin fill pattern through time and ultimately, the creation of the 4D model that in turn serves as the foundation of the Petroleum System Analysis. The basin evolution should be

self consistent - from structural development and assessment of accommodation space, to sediment thickness, to the facies filling the space. The maps should be annotated and the source of the interpretations as well as the confidence should be described.

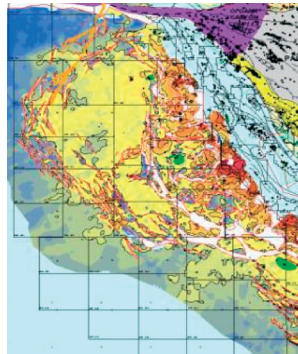
Middle Miocene facies



Middle Miocene structure & accommodation space



Middle Miocene isopach



STEP 6

Assess petroleum system

Initial steps involve integrating all the hydrocarbon occurrence data such as source rock observations from well penetrations and outcrops, oil and gas in wells, piston core extracts, seeps, slicks, hydrates and direct hydrocarbon indicators from seismic data.

Present day maturity can tell us the integrated history of a source interval. On their own, however, maturity assessments and maps can sometimes be misleading. To better understand the petroleum system, you can also look at **hydrocarbon flux through time**. For example, to pose an important question - Does the charge timing fit with the timing of reservoir deposition and trap formation?

Petroleum systems analysis involves more than traditional charge modelling. A complete understanding of charge modelling covers aspects of reservoir conditions through time. This is taken into account using programs such as Cauldron and Gridcharger. The petroleum system can be characterised most

The events chart helps identify the critical moment when all elements of a viable petroleum system are first in place.

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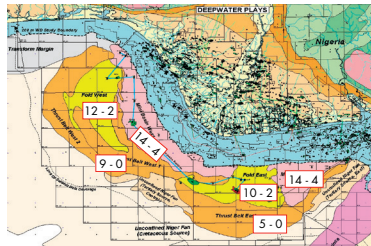
STEP 7

Trap distribution

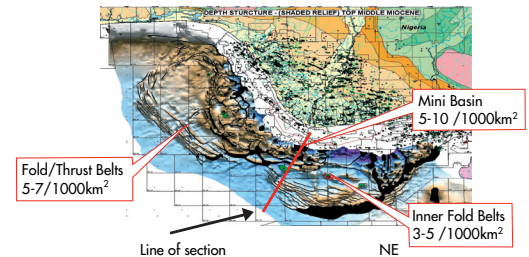
Palinspastic reconstructions (opposite) can provide information on the timing of structural development. Structural domains are generally spatially distinct

and mappable. Properties such as trap timing, size distribution, and structural lead spacing are similar within these domains.

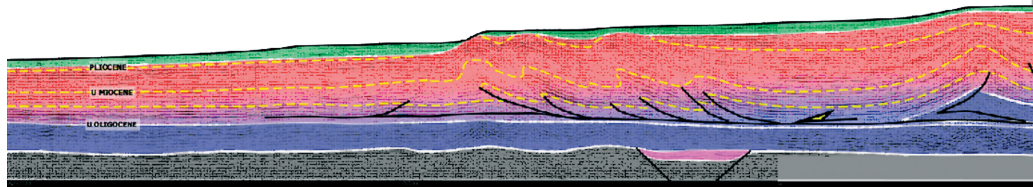
Lead density variation by structural domain



Structural Domains and Trap Timing



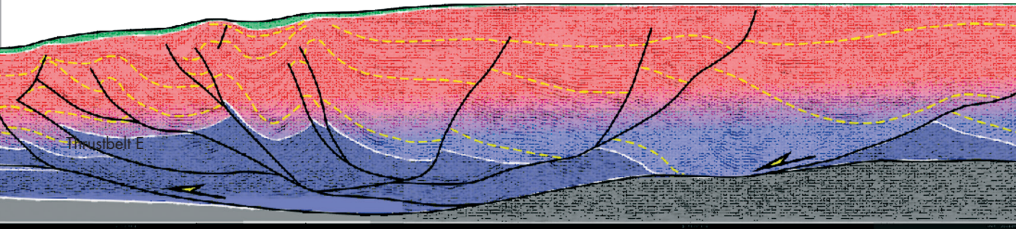
Inner Foldbelt Minibasin W



Today



Reconstruction - Lower Miocene



STEP 8

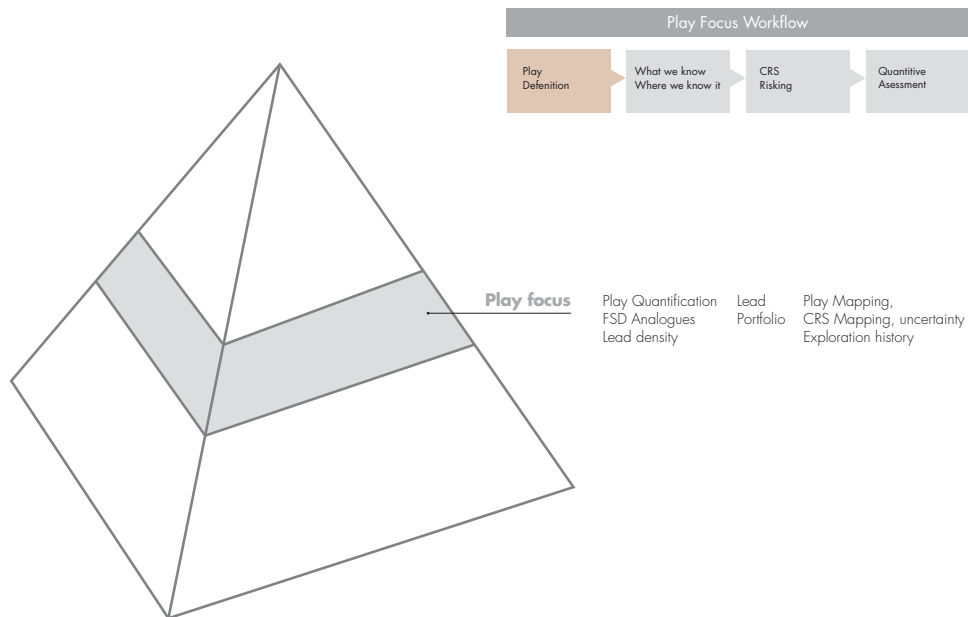
Identify plays

What plays are present in the petroleum system?

Chapter III

PLAY FOCUS

In the basin focus 'identify plays' leads us into the next level of the PBE pyramid - Play Focus.



THE PLAY FOCUS WORKFLOW

Step A. Play Definition - Take observations from Basin Focus and determine the logical number of discrete plays, and the areal distribution of each play.

Step B. Understanding what we know and where we know it - Assemble a **play test database**, which wildcats had technical success or failure after testing the play, identify why key wells failed. Show geological boundaries for the elements of the petroleum system: creating play element maps of **reservoir, charge and entrapment** (lithologic and structural elements of seal) and build a **summary play map**. In the absence of sufficient calibration data, identify **appropriate analogues** to build a model for the play.

Step C. CRS (Common Risk Segment) Mapping and Risking - Use play element maps and well data to define dependent and independent risk factors in the context of the proper confidence level. Convolve these maps to define the play “sweet spots” and reality-check the maps against the existing prospect portfolio.

Step D. Quantitative Assessment - Estimate volumetric scope and materiality (see appendix).

STEP A: Play Definition, Stratigraphic

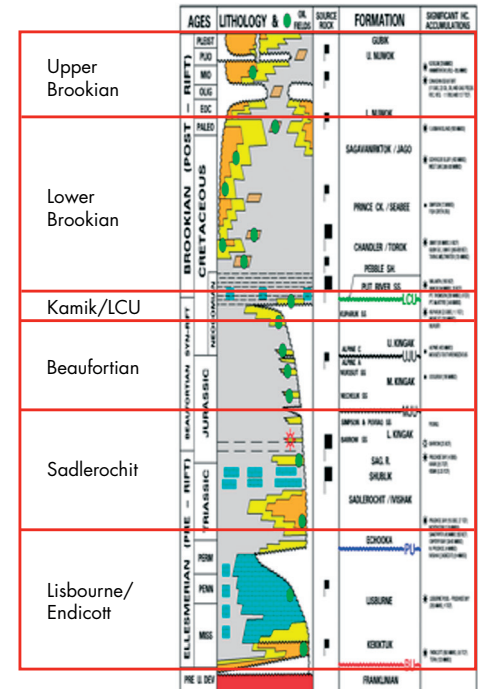
Stratigraphic definition encompasses the key reservoir and entrapment elements of the play and allows the main structural variation to be captured as segments of the play area. A single play map representing the entire section will probably represent a misleading grouping of several different distinct plays through the section.

Stratigraphic play boundaries should:

- Be no less detailed than megasequences.
- Reflect the maximum amount of detail of our current geological understanding.
- Have a clear line-of-sight back to our exploration objectives.

Stratigraphic Framework North Alaska

Plays Studied:



Plays are defined stratigraphically either by a significant change in the play elements:

- A major **bounding seal**.
- **Gross depositional environment** in the section.
- **Petroleum system** (for example, a younger source),

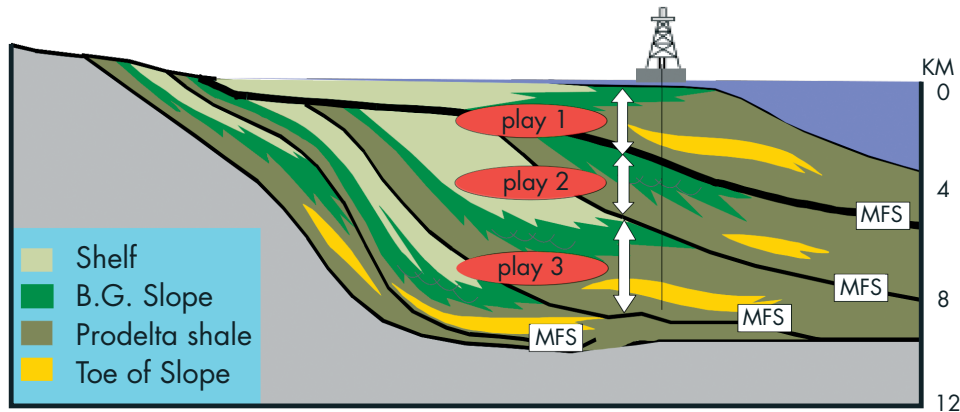
or other significant changes in the working geological model.

Play boundaries commonly share a **sequence stratigraphically controlled horizon** (e.g., a regional unconformity, mega-sequence boundary or maximum flooding surface).

The primary criterion for delineating plays is **regional or master seal**, usually associated with second- or third-order flooding surfaces. These regional seals often form **migration barriers** that can affect a whole family of prospects.

As a rule of thumb, a megasequence is the minimum level of fidelity for play analysis. Since a megasequence is observable on even sparse, greenfield basin data, most areas can be evaluated using play-based methods, even if there is no access to a complete set of detailed information.

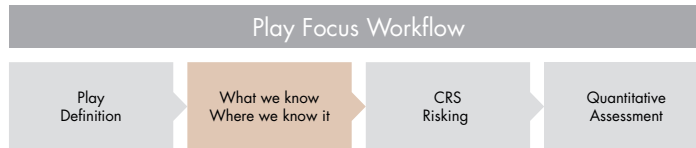
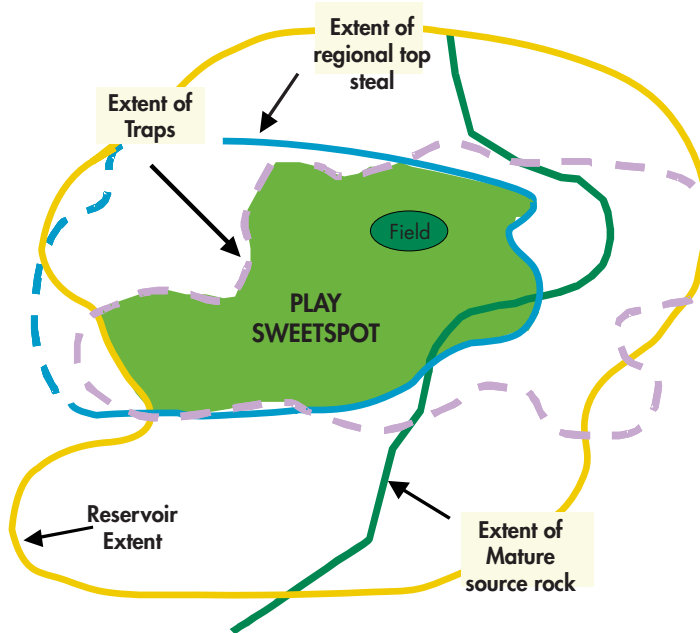
While a useful minimum threshold for defining plays, in most cases the use of megasequence boundaries grossly oversimplifies the number of stratigraphic plays. Typically, there are several vertical gross-depositional environment changes within a single megasequence.



Play Definition, areal

The areal play outline shown by the green colour below represents the maximum vertical coincidence of all of the elements of the petroleum system for this play: reservoir, charge and seal.

The play sweetspot should be a boundary outside of which there is ZERO chance that the play will be found (e.g.- reservoir and seal are totally eroded, source rock is at 10m below surface, etc).



STEP B: What do we know? Where do we know it?

Understanding the drilling history of the basin within the context of the plays is fundamental in tested basins. It yields a basic framework with which to interpret play boundaries, estimate chance and confidence (PoS), calculate technical success rates, and deduce the critical risk element(s).

1. Which wells are a valid test of a play?

A valid, play-testing exploration wildcat well is where the objective sequence had a chance to find trap, reservoir, seal and charge.

2. Which play-testing wells were technical successes?

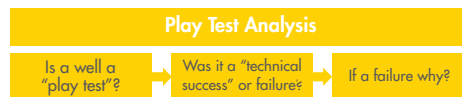
A technical success is a well with a flowable in-place volume at the formation level. This key definition is the threshold by which we risk prospects and plays.

3. Was the play-testing well a technical failure, and if so, why?

Understanding wildcat failure may be more important than documenting successes. Failure

analysis on key wells is a crucial step in finding why and where risk elements worked or didn't work.

For each element of the petroleum system (reservoir, charge and entrapment), create a map of boundaries, or segments that describe what we know and where we know it.



Building Play Element and Play Summary maps - Two factors should be balanced:

1. Make the boundaries as numerous as necessary to define the geology that drives success/ failure of a given chance factor.
2. Make the boundaries simple enough to relate back to definable geological trends that "speak" to the interpreter or decision-maker.

In some cases, the play element maps can be used across several plays (maturity and source rock distribution, for example).

A good play element map and play summary map should reflect geologic boundaries and:

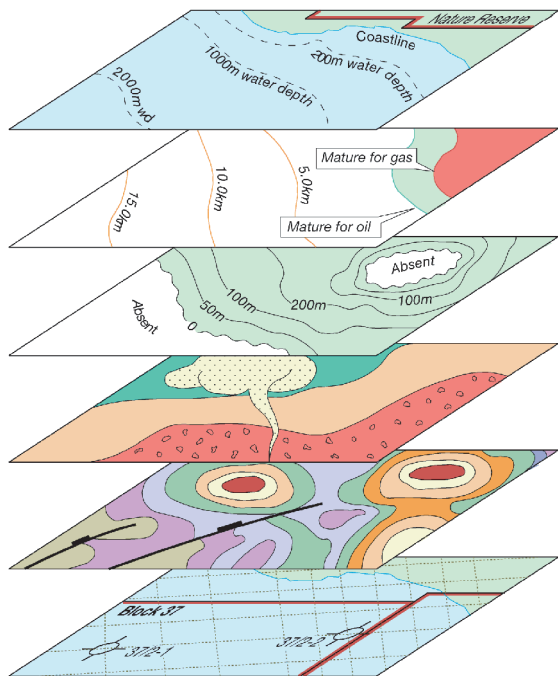
- Display wells within the stratigraphic play as technical successes or failures
- Have annotations of why lines were drawn and what data were used.
- Not be complex - capture the geologic trends for the chance factor: show how an exploration sweet spot in this play would occur.



Example: Reservoir Element (Segment) Map

N.B: If you don't capture the rationale, then subsequent explorers may not understand the maps.

Input data example



Focus map

ARC Gis/
Openworks Concessions
Partnerships

Source and Maturity Map

Flux map
Slicks/seeps
Inversion Timing

SR Quality
Temperature
Fetch map

Top Seal Isopach Map

TA I Fault seal risk
TAII Pressure Analysis
Timing

Reservoir Facies Map

Isopach
Porosity/PermNet/
Net to Gross

AVO/
Amplitudes
Provenance

Top Reservoir Structure Map

Tectono-strat Timing
Velocity Sensitivity
Fault Analysis

Database Map

Wells/Penetration Map
Success/Failure analysis
Risk statistics
Field Analogs





Play segment boundaries:

Should represent a significant change in geological model. E.g. a facies boundary as the boundary between shelf and slope depositional environments, location of sediment input points, channels, fan systems, delta lobes, etc. Two prospects drilled in relatively close proximity to, but on either side of this boundary will usually have different chances of success.

Should identify where confidence changes significantly.

Confidence reflects the density/ quality of information available and the interpreter's ability to

convert that knowledge into predictive models that define the probability of success.

Should be segmented to contain an appropriate amount of subdivision.

Ensure that boundaries are consistent with geological controls that drive large changes in technical success/ failure (e.g., VRE boundary, migration focus areas, facies, structural domains, etc.).

Boundaries (segments) should always be drawn based on geologic features, and not be drawn just to fit a well or prospect.

Play Focus Workflow

Play
Definition

What we know
Where we know it

CRS
Risking

Quantitative
Assessment

STEP C: Common Risk Segment (CRS) mapping and risking

Common Risk Segment: (CRS):

An area on a map that contains the same general chance for success (PoS) and confidence for a given chance factor: reservoir, charge, seal or structure, as defined in Shell's "Maastricht" risking template.

	Maastricht Chance Factors	Typical CRS Chance factor Maps
Play	PLAY RESERVOIR	Play PoS Reservoir
	PLAY RECOVERY	
	SR + PLAY CHARGE	Play PoS Charge
	PLAY STRUCTURE	Play PoS Entrapment
	REGIONAL SEAL	
Prospect	PROSPECT RESERVOIR	Lead PoS Reservoir
	PROSPECT RECOVERY	
	PROSPECT CHARGE	Lead PoS Charge
	PROSPECT STRUCTURE	Lead PoS Entrapment
	PROSPECT TOP SEAL	

(data quality and/ or density). Probability values are assigned to each segment.

The number of maps or chance factors that go into the CRS mapping exercise may vary, but experience has shown that play-level and prospect-level maps for Reservoir, Charge and Entrapment are usually sufficient to describe the risks. If more are needed, make sure they are included.

There are **four steps** to the CRS Risking workflow:

1. Determine the confidence level of the chance factor for which you are assigning PoS
2. Assign a Play PoS to the segments
3. Assign a Lead PoS to the segments
4. Create an amalgamated total PoS map and perform a reality check.



For some people it is easier to start from a view on the total pos for a chance factor, and then separate out the shared (play PoS) and local (independent or lead PoS).

CRS mapping and risking uses all available geological and exploration history data to create a view of the play-scale risks and dependencies. This work follows upon the play element mapping, and uses the boundaries (segments) created during that work.

The play is divided into segments with similar probability characteristics, with the boundaries reflecting changes in either geology, or confidence

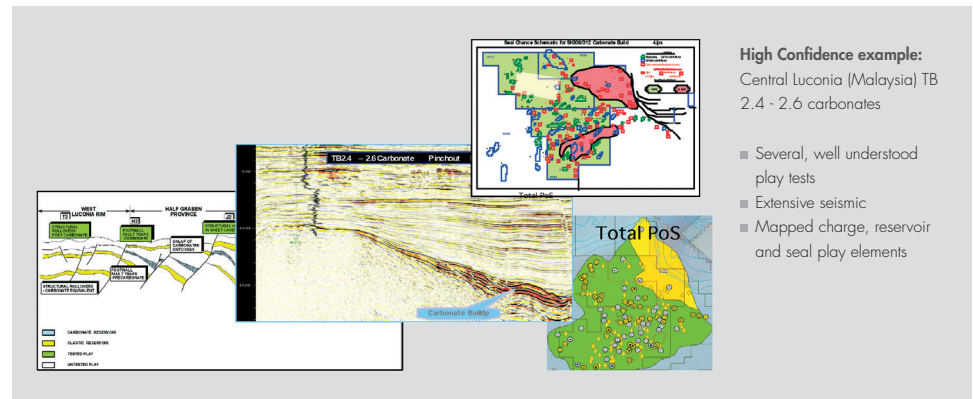
Determine confidence levels for each segment

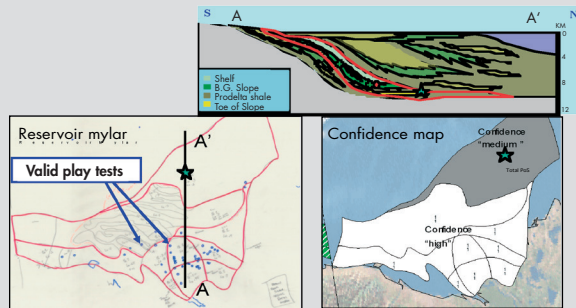
What are typical confidence levels for play analysis?

HIGH: Existing geologic models are robust enough to predict confidently where the chance factor is a success or failure. Several valid, analyzed play-testing wells exist. Dense 2D or 3D seismic with good imaging exists on which play elements (charge, reservoir, entrapment) can be mapped or modelled, play analogues exist.

MEDIUM: Existing geologic models help to show where the chance factor may work. Intermediate to coarse 2D seismic exists, some regional maps and geological models of play elements have been made. Play testing wells may or may not exist.

LOW: Very little to no primary or secondary data exist to support a geologic model or suggest where the chance factor works. Little or no seismic coverage. Quick-look analysis relying primarily on analogue data.



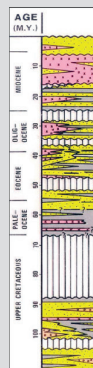
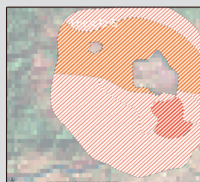
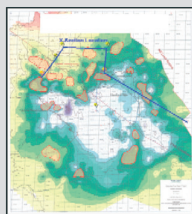


Medium Confidence example:

Mackenzie Delta (Canada),
Taglu base of Slope Turbidites

- Sparse valid play tests in similar play segment
- Regional 2-D seismic
- Reservoir facies model

Magnetotellurics map



Low Confidence example:

Colombia River Basin sub-basalt
Continental clastics

- No sub-basalt image
- Speculative stratigraphic column based on sparse well data
- Play relies on regional, conceptual basin evolution concept pinned to global analogue

Some areas of play conceptually "better" than others, but all are heavily hachured to reflect low confidence



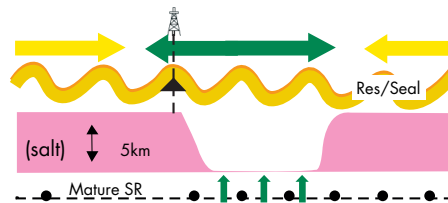
Assign play PoS and average lead PoS

Play PoS (shared PoS):

Probability of trapped hydrocarbons being present and capable of being produced from the formation somewhere in the play segment - irrespective of volume, rates, and economic criteria

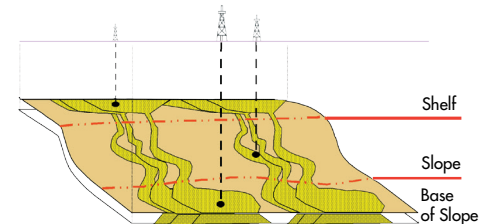
Example: Play PoS Charge

Assuming no lateral migration, all of the prospects above the thick salt would fail for the lack of charge. Because of this dependent failure risk, the play PoS for charge in the segments with yellow arrows would be very low, even though the play works in the green arrowed segment.



Average Lead PoS (Prospect Success Ratio):

Percentage of prospects predicted to be hydrocarbon bearing (expected success rate), or probability that an average lead or prospect would be a technical success, assuming the play is proven. It's a measure of the repeatability in a play segment.



Example: Average lead PoS reservoir

In this example, all of the play reservoir segments are proven, since there are discoveries within each of the geologic domains.

The repeatability of finding reservoir in prospects is higher in the base of slope segment than the channel-prone slope.

Repeatability = Average Lead PoS = Success rate
for the chance factor in each segment

Shell's 2004 risking template, also known as the
Maastricht template is used to determine unbiased
prospect and play chance factors.

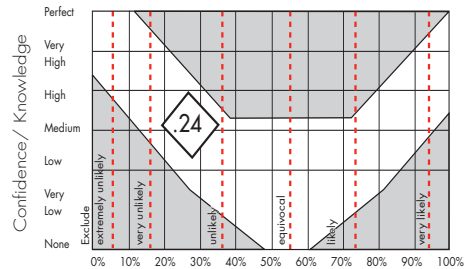
Example Reservoir (below):

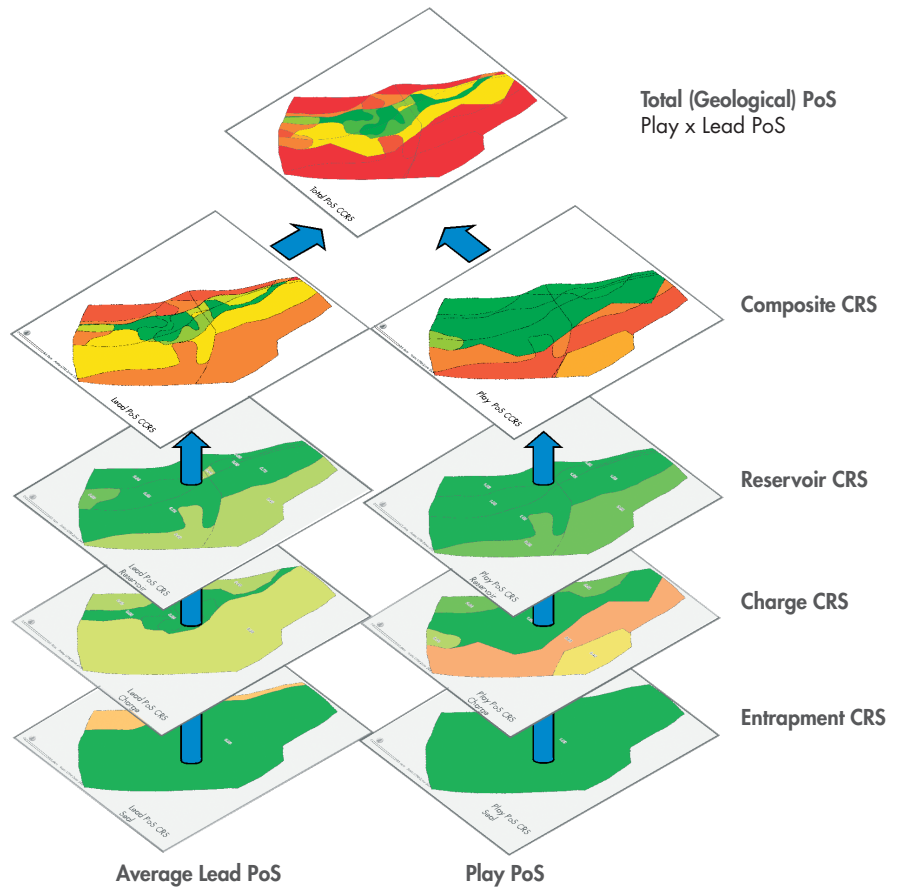
Medium Confidence,

Play PoS = 0.8

Lead PoS = 0.3

Total PoS = $0.8 \times 0.3 = 0.24$)





In the last step of CRS Risking we multiply the maps together to create Composite Common Risk Segment (CCRS) maps. A reality check against known data is then preformed. By multiplying the play and lead PoS CCRS maps, we can approximate total geological PoS.

Reality Checks:

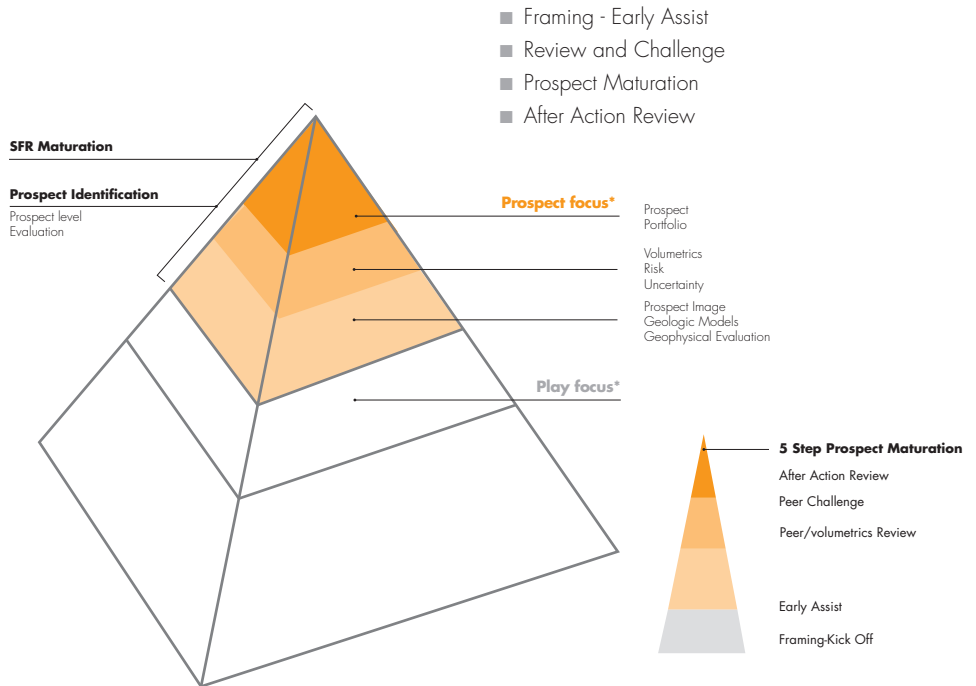
- Do the CCRS maps reflect our intuitive picture of for the average prospect PoS within each segment?
- Does the PoS compare with the exploration history and prospect portfolio? For proven segments (play PoS = 1.0). Does the lead PoS make sense in the light of historic success rates? When plotted on a CCRS map, are prospect risks representative of the average PoS portrayed by the play analysis and do the prospect PoS values change across key boundaries?

- Does the resulting map still show clearly the key trends of the play or does the map look like shards of glass? Often such maps reflect a level of detail not supported by the data available, and are more detailed than the level of knowledge needed to answer the relevant technical exploration questions.



Chapter IV

FROM PLAY FOCUS TO PROSPECT FOCUS



When evaluating prospects and prospect portfolios we should place them in a play context. This gives us strategic information needed to de-risk the play and assess the prospect's ability to deliver Scope for Recovery (SFR) volumes. We ultimately can also understand the additional potential (yeHto-find - YTF)

in related prospects within the same play or play segment. It can shorten prospect evaluation by giving a focus to the work. Such as the identification of the success factors needed and the likely failure modes for the prospect as predicted by the regional risk elements.

Framing - Early Assist
Key Products
Play Cross Sections
Play & CCRS maps

Play Element CRS maps

Exploration History Analysis

Review & Challenge
Play & CCRS maps
Play Element CRS maps
Exploration History Analysis
FSDs
Materiality maps
Play YTF, CSFs
Play Execution Plan
Well Plan

AAR
Multiple PBE products

Key Questions

Can the focal Play be succinctly described on a cross section ?
Does exploring in this Play segment have merit based on Regional Sweet spot analysis ?
What geological aspects of the Prospect should be the main focus of the evaluation work (I.e. likely failure modes) ?
What can we learn from the Exploration history to best augment the evaluation and improve our understanding of the prospect ?
What does the history indicate as good analogues to use ?

Does maturing view of the Prospect reconcile with Play Segment Risking ?
Prospect Risking consistent with Play PoS maps ?
What phase of Play Creaming is the Prospect In ?
Does Prospect volume range fit the appropriate FSD ?
Is there likely material follow up to a well test ?
Does the Play and Play segment have enough running room ?
Does prospect test fit in agreed Play execution plan ?
Does well plan contain provision for key Play data gathering ?

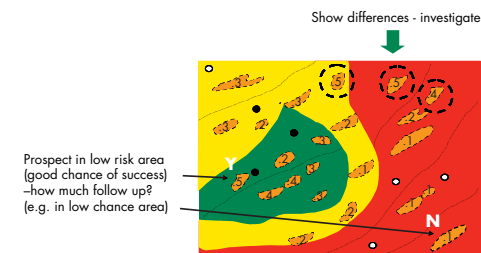
Have well learnings been fed back to evergreen basin and play understanding ?

Specific guidelines exist for how prospects and prospect portfolios can be placed in the play context - what **key play-based products** should be used. These include play CRS maps, Field Size Distributions (FSDs - see appendix), YTF estimates etc. The table shows **key questions** that should be addressed at various phases of the **5 step maturation process** - deliverables on value drivers, critical success factors, project risks, project plan, volumetrics estimates etc.

Examples of prospects in a play context

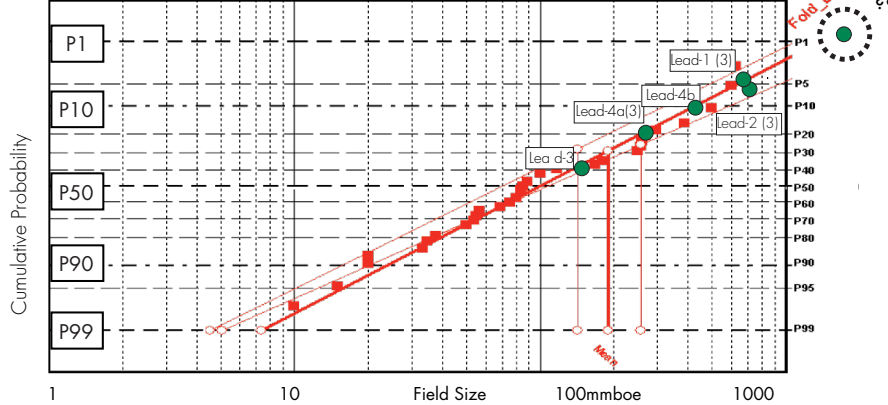
We can ask questions about how reasonable prospect risks and volumes are when compared with the play based evaluations.

A prospect portfolio is overlain on the corresponding composite common risk segment (CCRS) play

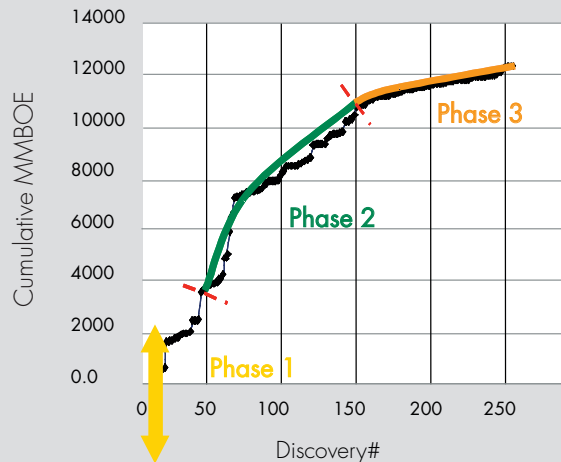


In certain cases, prospect MSVs may exceed the

As a further test, we can place the prospect in the appropriate place on the play segment creaming curve. This is characterised in three phases.



Typical Play Specific creaming curve



Note;

1. Quick play or segment calibration will allow better, earlier decision-making.
2. Confident exploration for material prospects only starts in Phase 2
3. Phase 3 prospectivity should be measured against exploration value generation and strategy for the basin

The creaming context of the prospects should dictate the reasonable expectation of their potential volume and value delivery.

Phase 1 - Play Testing/ Calibration

Technical risks poorly constrained and few or no exploration tests. Early information is key to decisions on play participation.

Phase 2 - Play harvesting

The play is calibrated for risks and volumetrics and maturation is designed to maximize SFR return, assisted by appropriate technology deployment.

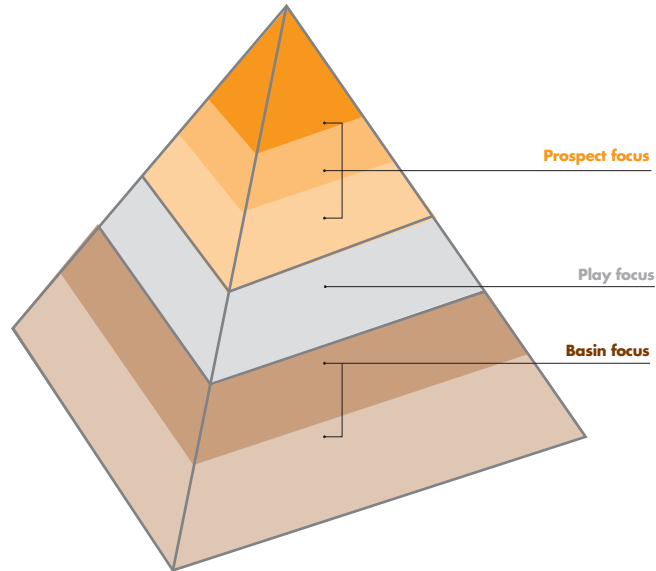
Phase 3 - Maturity

Few material opportunities remain. Often a Near Field Exploration (NFE) phase optimizing value. As returns diminish, play exit may become the preferred option.

Chapter V

VENTURE EVALUATION

Good PBE Practice involves building first the basin, then play and then the prospect understanding. Exploration strategy, planning and execution are therefore based on the foundation of understanding the plays in a venture.

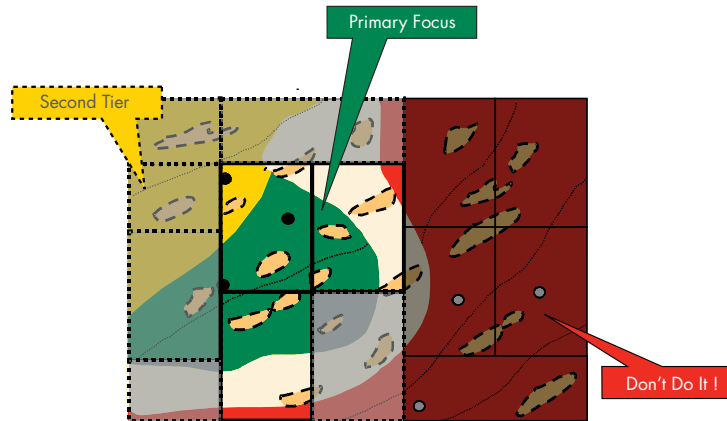


A basic understanding of the subsurface and its potential is our greatest strength. Other 'TECOP' factors (economics, commercial, operational and political) should be also overlain on the play-based view of a venture or opportunity to arrive at the appropriate decision. Remember -

"The best contract terms, price fluctuations, politics or acreage access conditions do not put valuable, material hydrocarbon plays in the ground or close contours on maps..."

Securing a material position requires us to quickly identify key plays and focus on the sweet spots.

So early identification of and access to the play sweet spots is vital. In some recent cases, late play identification led to expensive access where our initial acreage position was not in the sweet spot.



Building an exploration plan for the focus play

Address the key points for the focus play;

- Principal technical play risks.
- Risk dependency within the portfolio.

- Maximise volume capture in the short and long term.
- Quick strategic decisions—more acreage or exit?

To understand prospect value of information and play upside:

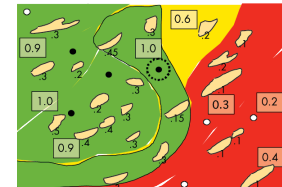
Use (dependent) Play Pos CRS and Materiality maps to assess zone of influence from a possible well test.

0.9 Ave Play Pos



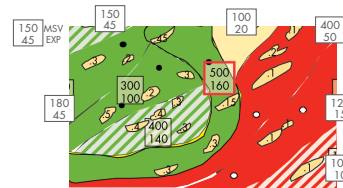
PoS Uplift
throughout Play
segment due to
reduction of
dependent
Play Risk

0.9 Ave Play Pos



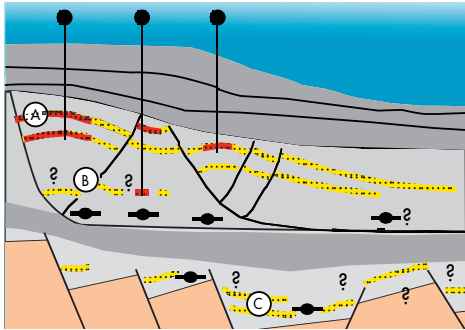
Targeting Play Segment with Running Room

Use YTF and Materiality maps to assess Play Segment Volume Prize



Building play optionality into the Venture Plan

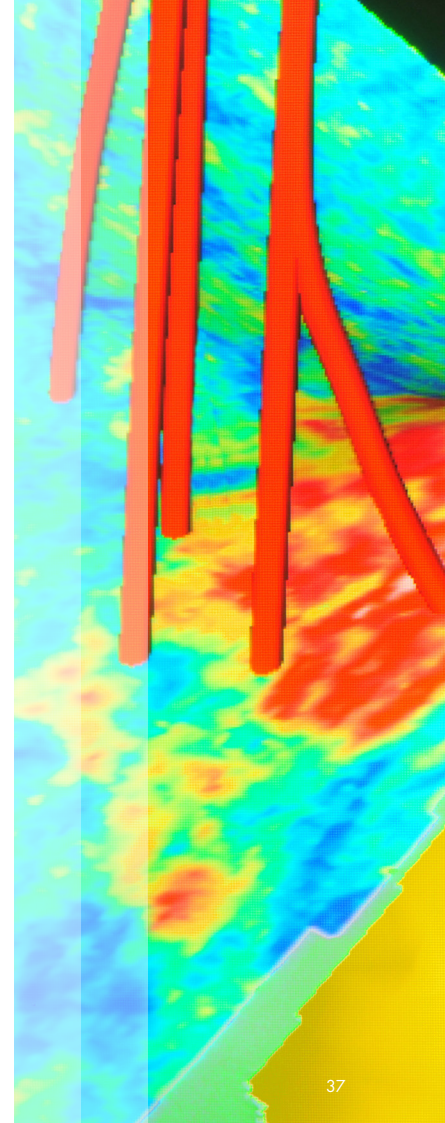
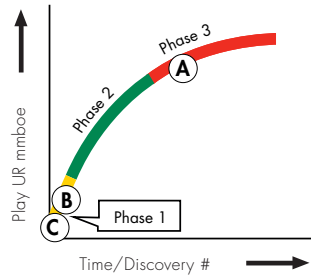
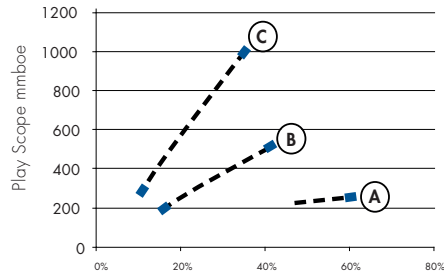
A typical basin venture will contain several plays and often each of these at different stages of understanding and technical maturity. Ideally, Venture Plans should be built with a clear view of the play scope or ability to deliver SFR volumes together with the information needs of each of the plays, key decision points and an understanding of the possible inter-relationships between plays.

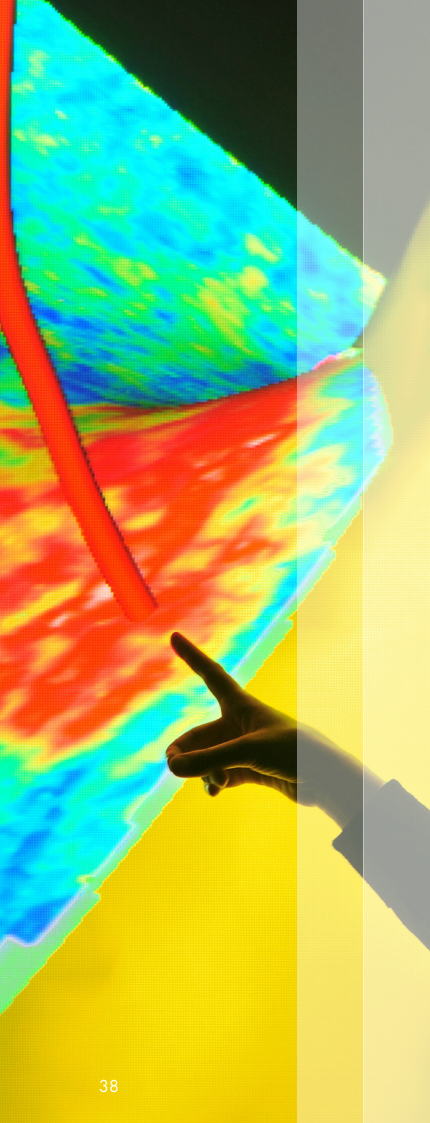


In this schematic example, Play A is proven and mature, B is technically proven but still poorly understood and C is largely conceptual but with significant scope.

The variety of these plays requires a different approach for the execution plans for each.

Play Scope vs PoS

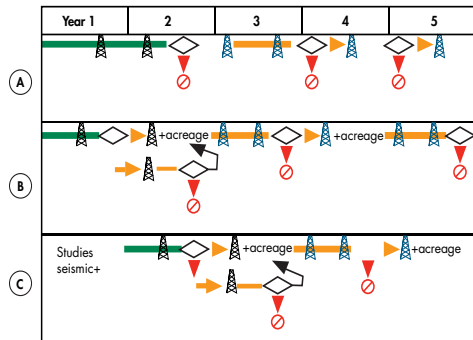




A Venture Plan for these plays could look like this:

Play A is well calibrated such that most of the remaining drilling opportunities have only independent (lead) risk. The “learning value” of these wells is minimal and they can be most likely drilled out in the most efficient way as part of an NFE programme of low risk, low volume prospects. Future key decisions could be the optimal exit point whenever smaller discoveries suggest that exploration resource could be better spent elsewhere.

Partially calibrated deep **Play B** shares certain petroleum system elements with the shallow play A but overall the need for additional information in this emerging play is high in order to target early tests and quickly identify the sweet spot. Opportunistic deepening of a remaining play A prospect well to test the deeper play B is a clear option for efficiently building understanding in the deeper play but should always be measured against the cost of testing play B in an optimal location and the richer information that could come from that tactical choice. The plan for this play consequently focuses on the prospects that will get to a confident go forward/exit decision soonest.



Play C is unproven and shares no petroleum system elements with the shallower plays.

It should be treated as a Frontier play opportunity with the same importance in establishing basic petroleum system understanding - source rock presence, maturity, timing, reservoir/ seal pairs etc. In the absence of hard calibration data, play analogue information and primary delineation data such as high resolution gravimetric studies or long cable deep target seismic could form the basis of the early effort.

The follow-up to this effort could then be deep well tests to conclusively test the petroleum system elements.

The strong message here is to treat plays independently in execution planning and where relevant prioritize calibration efforts in new plays and... avoid committing to drilling consecutive and probably dependent wells back-to-back.

Appendix

Play Focus Workflow

Play
Definition

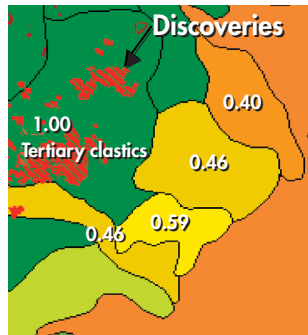
What we know
Where we know it

CRS
Risking

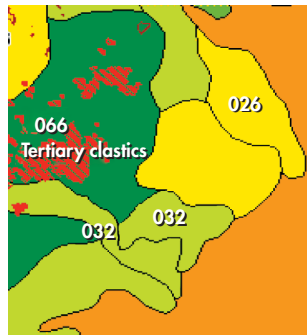
Quantitative
Assessment

STEP D: Quantitative aspects of Play-Based Exploration

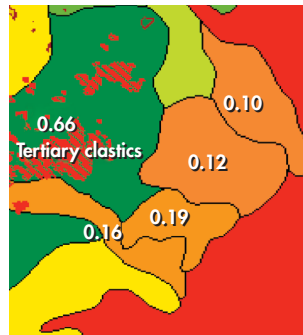
(in play focus)



Play PoS



Avg. Lead PoS



Total PoS

The numerical basis of PBE analysis

CRS maps alone, however, do not answer other business questions, e.g:

- What does success look like? - scope - materiality
- What will the portfolio achieve?
- What is the chance of achieving success (a venture question)?
- What is the at-risk financial exposure (not covered here)?

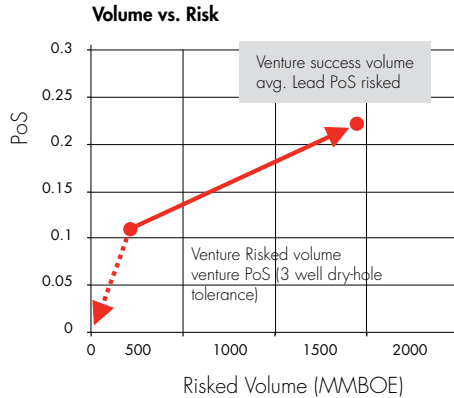
To answer these questions, an assessment of volumetric potential is required.

The “Play focus” (section III) described where in the basin the best chance of achieving exploration success is maximized. The segments containing discoveries (highlighted on the maps above) are proven and thus have a play PoS of 100%. The segments to the east are, as yet, unproven and have play PoS values less than 100%. The total PoS on these segments is very low.

The rationale for breaking out play and average lead PoS

- From a portfolio of segments perspective, it is critical to understand both the play and average lead PoS to evaluate the chance of venture success.
- To understand and communicate what one of the unproven segments would look like if successful, however, the average lead PoS is used.

Describing play segment volumes

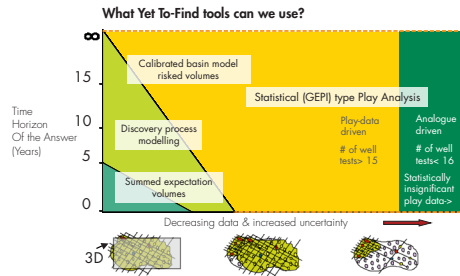


The chart shows the difference between a success description of an unproven play segment (**venture success risked volume, the upper right point**) and the portfolio description (**total venture risked volume, lower left point**).

The difference between the two points describes the potential volume that can be achieved by proving up a play segment in a successful venture. If the venture is unsuccessful, however, the volume is zero (dashed line).

The venture risked volume description is only useful from a portfolio perspective (roll-up of a number of segments), since the ultimate outcome from drilling up any single play segment is either the success case, or failure case. In a proven segment the venture risked and venture success volumes are the same.

This type of plot also clearly illustrates the potential value of information obtainable from a given well or farm-in. A variety of tools can be used to provide the volumetric description. Their usage depends on the time frame of interest in the analysis and the amount of data available.



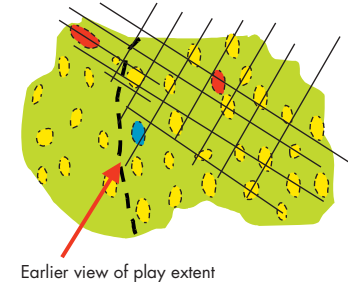
Deterministic methods for volumetric assessment

1. Summed prospect expectation volumes

Elements to be considered

- How good are the prospect expectation volumes?
- Is an economic minimum being considered?
- Has the data density given a complete lead inventory?
- Has a "dry-hole" tolerance been factored?
- Has the full extent of the play been identified?

Play with lead inventory and synthetic leads

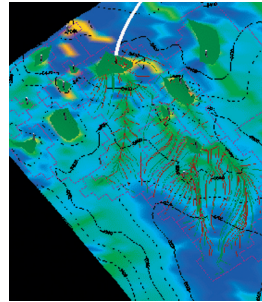


2. Calibrated basin model

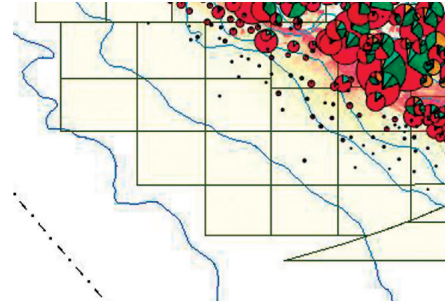
Quantitative play analysis tied to charge models allows rapid testing of different scenarios with the ability to see the results quickly for block or play segment ranking.

A quality control check on predicted versus actual results is required.

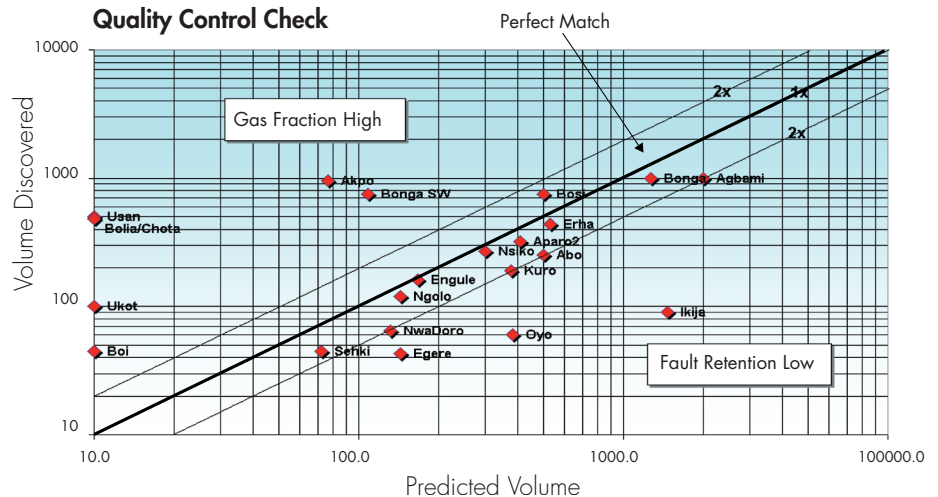
Due to incomplete data, deterministic methods may not provide a complete view of a play or play segment, e.g. in frontier areas, and new Shell entries. In these situations, a **statistical** volumetric assessment can provide the critical information.



Expulsion and Migration



Volume and Fluid Prediction



3. Statistical (GEPI) type play analysis

All statistical methods are built upon
3 basic components.

The terms of statistical analysis:

Total PoS: (Play PoS x Avg. Lead PoS)

The calculation uses both figures not just the rolled-up Total PoS.

Future Field Size Distribution (FSD):

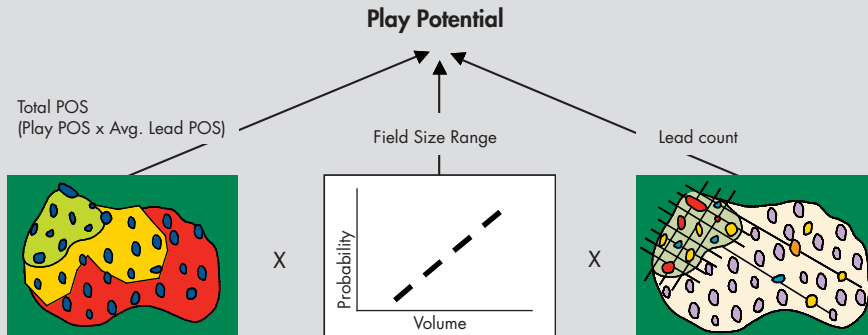
A numerical distribution reflecting the range of undiscovered future accumulations (EUR) in a play or play segment, including sub-commercial accumulations (Presented in a cumulative log-probability plot).

Lead Count: The number of potential leads in a given segment of analysis.

Often calculated from a lead density, typically expressed in # / 1000 km².

The Basic Equation:

Play potential= Total POS (@ zero cutoff) * Future FSD * Remaining lead count



Each of the elements has pitfalls. These must be understood in advance.

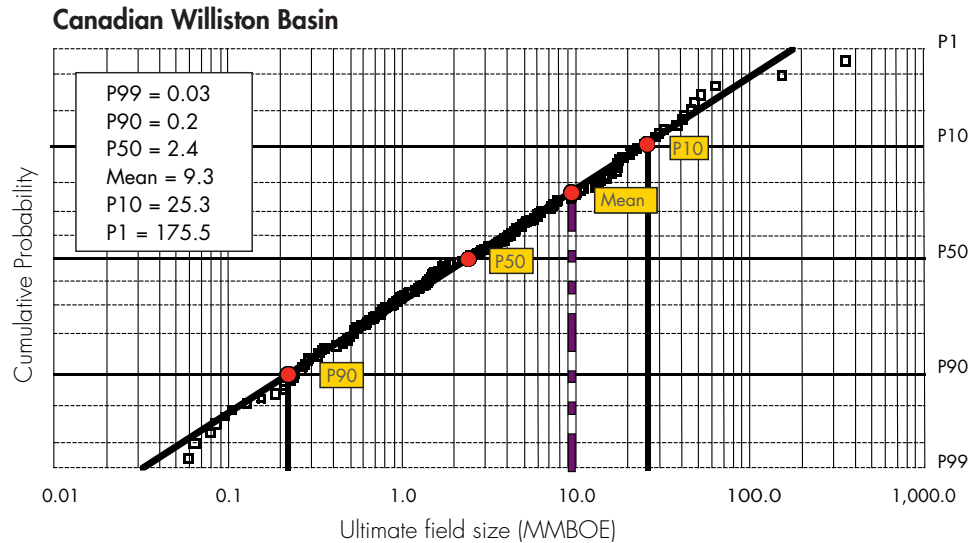
Past scepticism of results from this approach are not because the method is flawed (our competitors have borne this out), but in many cases because of careless or poorly constrained inputs.

No outcome gives the "right answer" (as with any model), therefore we must use ranges to indicate the results.

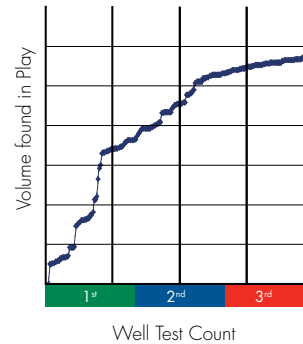
Williston Basin field size distribution chart

A field size distribution (FSD) provides a considerable amount of information about a play or play segment. From the example above:

- Any randomly selected field has only a 10% chance of being larger than 25 million barrels;
- 50% of the discoveries are smaller than 2.4 million barrels.



Play Creaming Curve



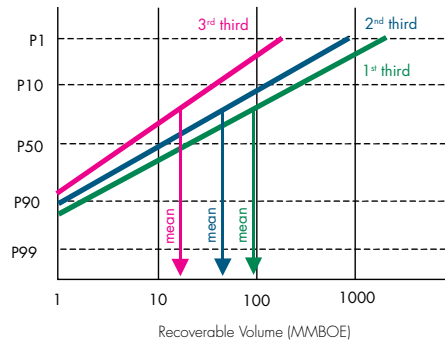
A field size distribution represents a “snapshot” in time

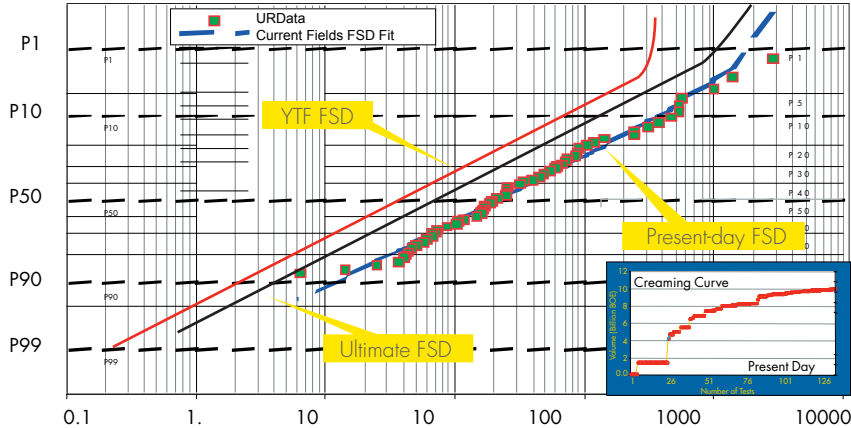
A history of discovery volumes in a play shows the FSD of the 1st third of the discoveries is larger than the 2nd third, which, in turn is larger than the 3rd. This is a representation of exploration “creaming”.

A forward-looking FSD is required for a Yet-To-Find exercise in partially creamed play segments

Producing an FSD for a volume assessment requires a forward (YTF FSD) look at the potential field sizes yet to be discovered. The previous examples show existing (already discovered) size distributions. These should not be used for a future look assessment. The analysis would then result in the simulated “discovery” of fields that have already been found in a partially creamed play segment. Native FSDs however, may be used as analogues for frontier areas, or in new play extensions (e.g. same play projected under salt where imaging problems precluded exploration in the past).

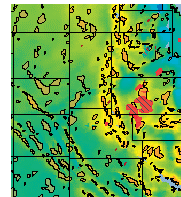
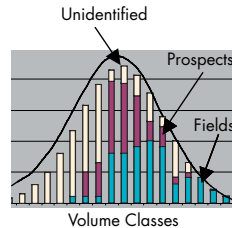
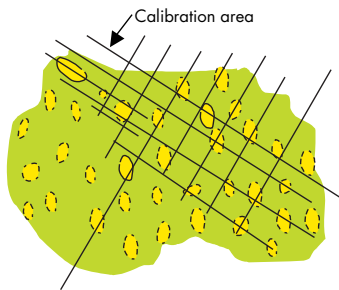
FSD Chart





Producing an appropriate lead count

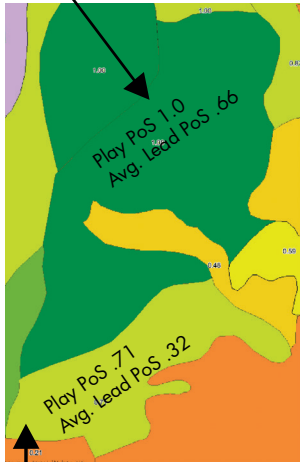
- New / immature plays - start with lead density per 1000 km² from appropriate geologic analogue (with sufficient exploration maturity).
- Play extensions - extrapolate lead density per 1000 km² from an extensively explored similar 'calibration area'.
- Map-based trap delineation (basin models).
- Discovery Process modelling: Top-up method - e.g. FSDDecoder / PlayCraft (counting the number of unidentified leads that fit under a log normal distribution).
- There should be a balance between the lead density and the FSD (how many billion barrel fields can fit in 1000 km²?).



Demystifying the “GEPI” calculation (PoS x FSD x Lead Count)

Proven play segment

Venture Risked = Venture Success



Play CCRS map

Unproven play segment

Venture Risked = Venture Success

Play PoS = 1.0

Avg. Lead PoS = .66

Lead Count = 13

Mean FSD = 25

Venture Volume = $.66 \times 25$ (mean of FSD) $\times 13 = 214$ MMBO

Venture Scope = $.66 \times 13 = \sim 8$ successes (8.6)

Materiality expectation ~ 1 lead > 66 MMBO

Play PoS = .71

Avg. Lead PoS = .32

Lead Count = 30

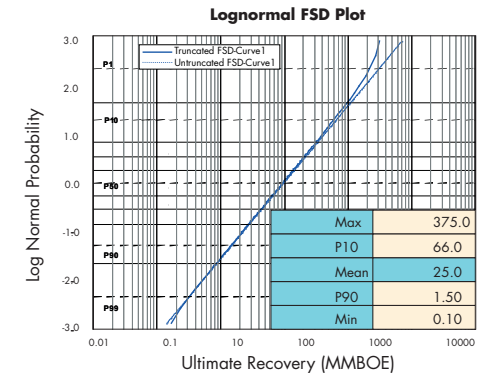
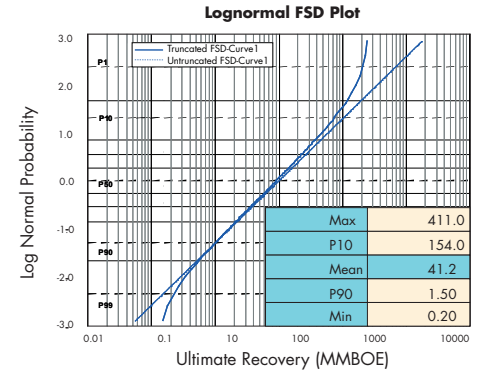
Mean FSD = 41 (totally uncreamed segment)

Total Venture Risked Volume = For portfolio roll-up

$.71 \times .32 \times 41$ (mean of FSD) $\times 30 = 279$ MMBO

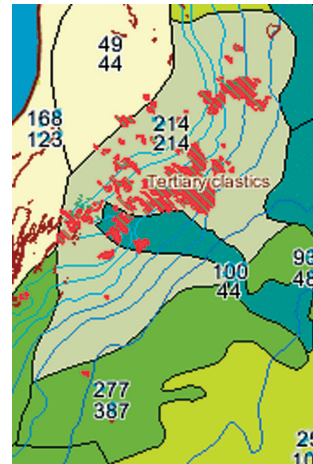
Total venture risked scope = For portfolio roll-up

$.71 \times .32 \times 30 = \sim 7$ successes (6.8)



Would we ever expect to find 7 successes in this segment? No! If the segment fails, nothing will be found, and if it does work, then we need to look at the success case.

This number is only useful from a roll-up of a portfolio of segments perspective



What would success look like?

Venture Success Volume = $.32 \times 41 \text{ mmbo} \times 30 \text{ leads} = 394 \text{ MMBO}$

Scope with play success = $.32 \text{ lead PoS} \times 30 \text{ leads} = 10 \text{ successes}$

Materiality expectation ~ 1 lead > 150 MMBO

GEPI venture success simulation output map from BPA (segment colours

reflect success HC richness). Smaller number is total venture risked volume prediction, larger number is venture success risked volume prediction.

NOTES

NOTES

