Economic Risk and Decision Analysis for Oil and Gas Industry
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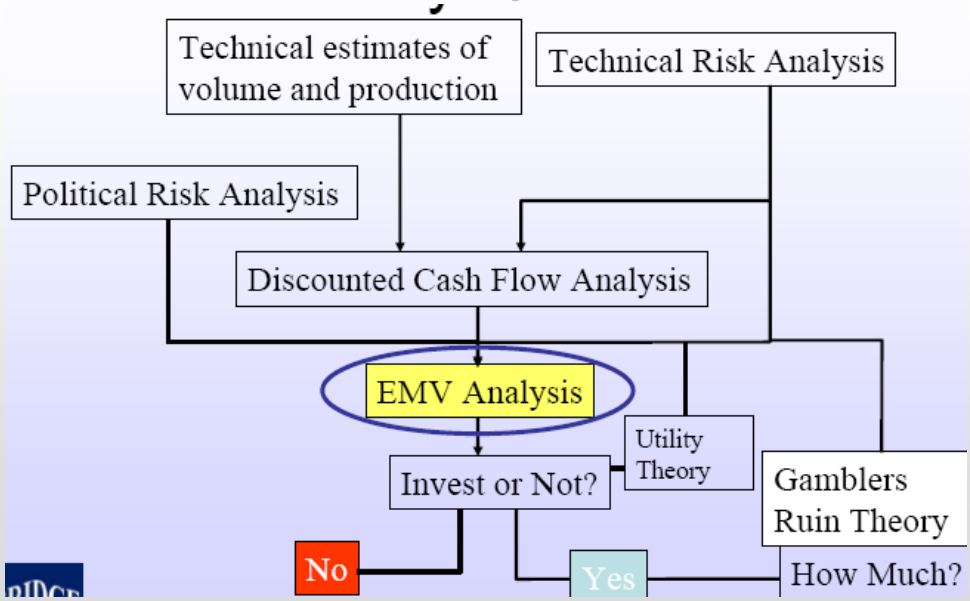
Risk Analysis Methods

Risk Analysis Methods

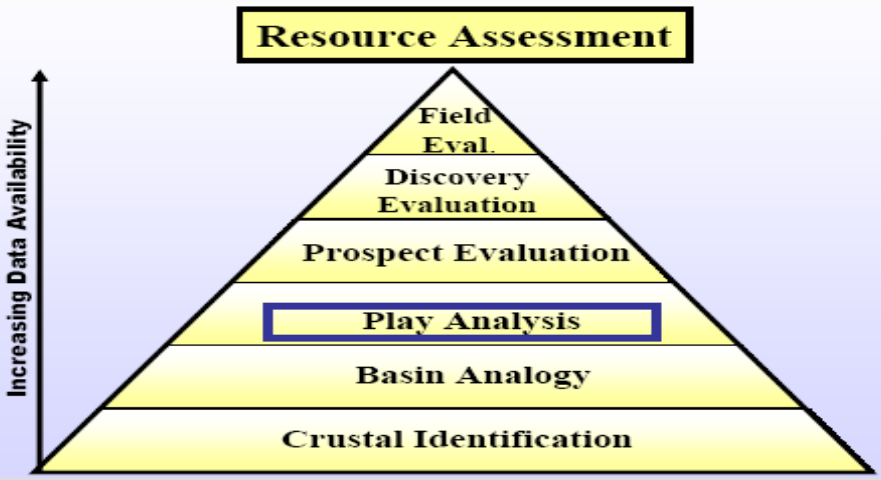


Technical/Geological Risk Analysis (Probability of Success)

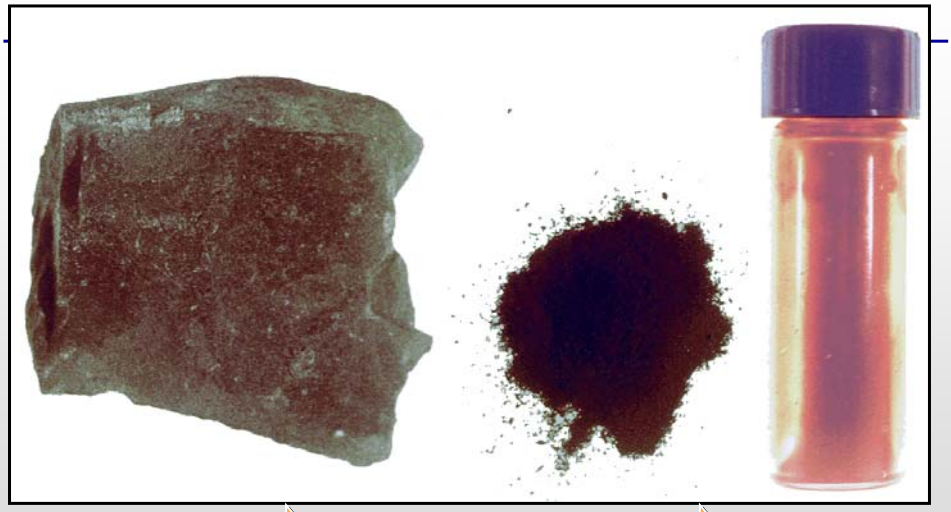
Petroleum Resource Assessment

- Estimation of the total volume of recoverable Hydrocarbons, discovered and undiscovered, in a given area
- The chance of finding and producing the hydrocarbons economically

Petroleum Resource Assessment



The Origin of Petroleum



Organic-rich Source Rock → Thermally Matured Organic Matter → Oil

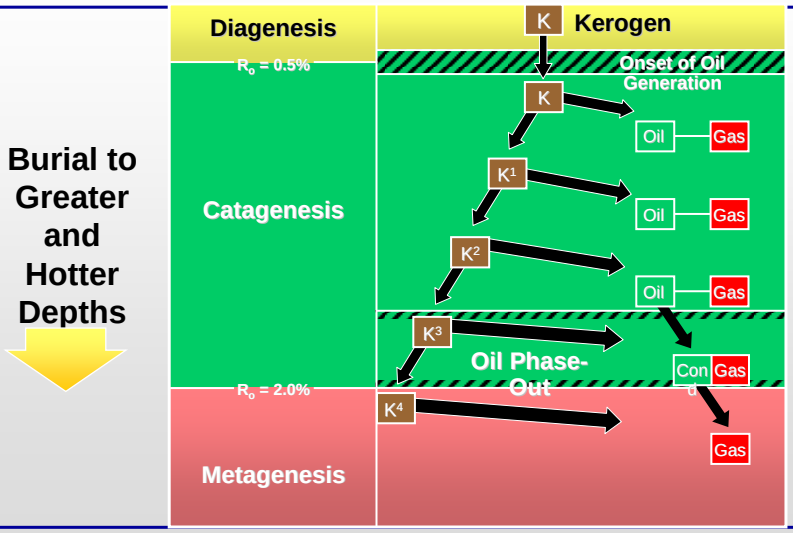
Types of Petroleum

Oil and gas are formed by the thermal cracking of organic compounds buried in fine-grained rocks.

Algae = Hydrogen rich = Oil-prone

Wood = Hydrogen poor = Gas-prone

Thermal Maturation History



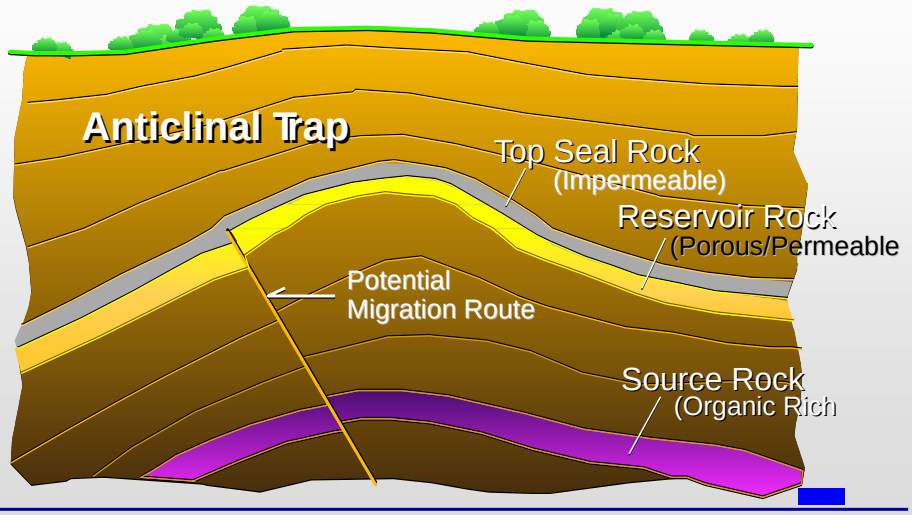
Horsfield and Rullkotter, 1994

Petroleum System Definition

The essential **elements** and **processes** and all genetically-related hydrocarbons that occur in petroleum shows, and accumulations whose provenance is a single pod of active source rock.

Elements	Processes
Source Rock	Generation
Migration Route	Migration
Reservoir Rock	Accumulation
Seal Rock	Preservation
Trap	

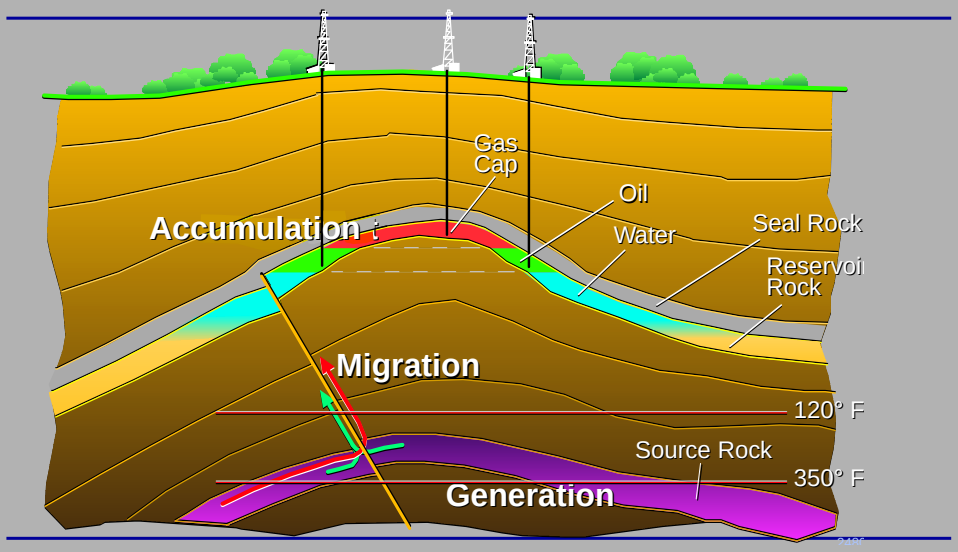
Petroleum System Elements



Petroleum System Elements

- **Source Rock** - A rock with abundant hydrocarbon-prone organic matter
- **Reservoir Rock** - A rock in which oil and gas accumulates:
  - -Porosity - space between rock grains in which oil accumulates
  - -Permeability - passage-ways between pores through which oil and gas moves
- **Seal Rock** - A rock through which oil and gas cannot move effectively (such as mudstone and claystone)
- **Migration Route** - Avenues in rock through which oil and gas moves from source rock to trap
- **Trap** - The structural and stratigraphic configuration that focuses oil and gas into an accumulation

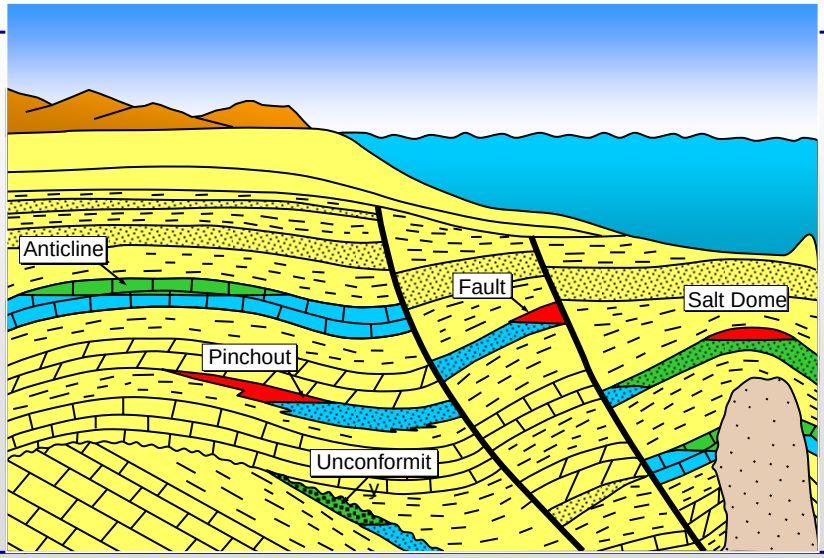
Petroleum System Processes



Petroleum System Processes

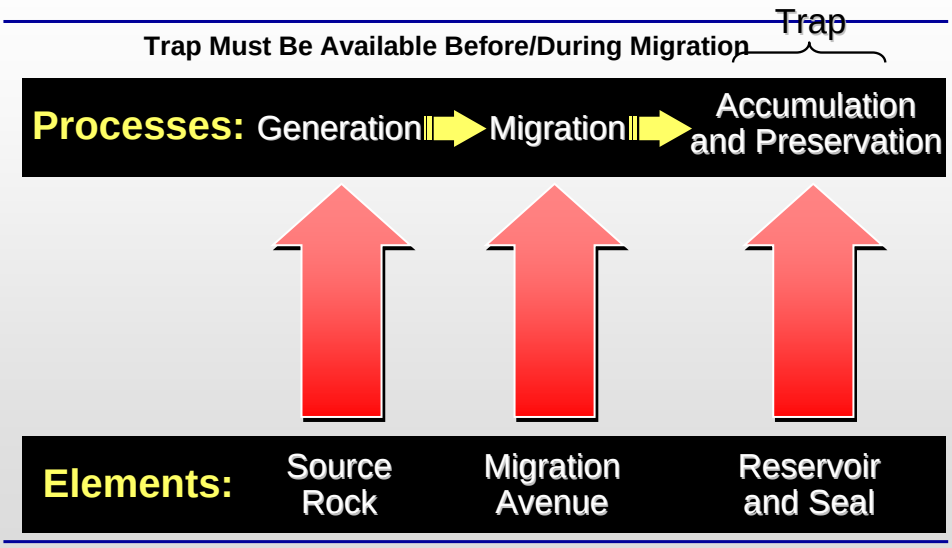
- **Generation** - Burial of source rock to temperature and pressure regime sufficient to convert organic matter into hydrocarbon
- **Migration** - Movement of hydrocarbon out of the source rock toward and into a trap
- **Accumulation** - A volume of hydrocarbon migrating into a trap faster than the trap leaks resulting in an accumulation
- **Preservation** - Hydrocarbon remains in reservoir and is not altered by biodegradation or “water-washing”
- **Timing** - Trap forms before and during hydrocarbon migrating

Hydrocarbon Trap Types



American Petroleum Institute, 1986

Petroleum System: Timing is Critical



Petroleum System

- Petroleum system.
  - A group of plays within a given geographical area having a common source rock.
- Play.
  - A geographically and stratigraphically delimited area where common geological factors exist in order that petroleum accumulation can occur.
- Prospect.
  - A potential petroleum trap.
  - With a mappable reservoir rock volume.

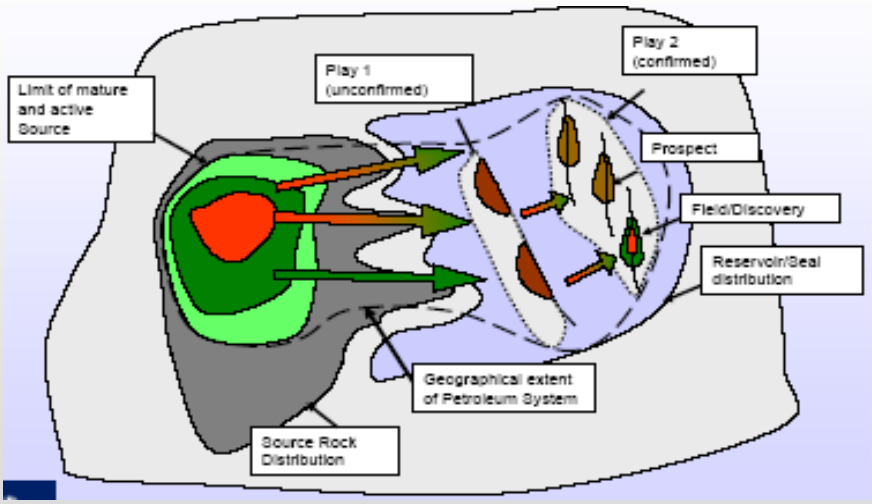
Play Definition (Duff&Hall, 1995)

- One or more closures of similar structural, depositional or hydrodynamic style, which result from a specific set of tectonic, depositional, diagenetic or halokinetic processes within a sedimentary basin, and which with suitable reservoir and sealing lithologies, and hydrocarbon charge, may form prospective hydrocarbon traps

Play Attributes

- Existence of a Mature Source Rock in Possible Drainage Area of Traps
- Existence of sealed Traps formed prior to the end of Hydrocarbon Migration
- Existence of Reservoir Rock

Petroleum System



Risk Levels

Split into prospect level and play level.

- Play attributes assumed to be common to all prospects in the play are grouped in the play level.
- Prospect risk factors are assumed to be unique for each prospect and estimates vary from prospect to prospect.

Play and Prospect Risk

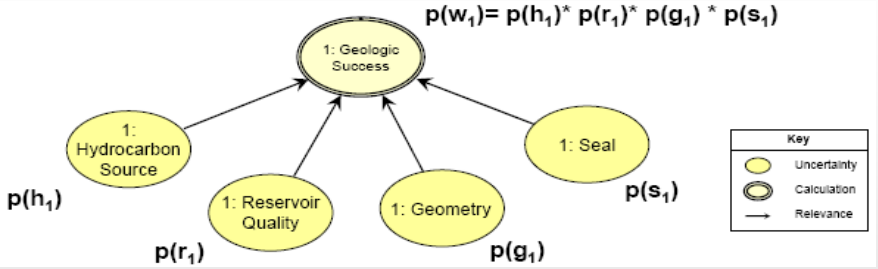
Risk Model	
Play risk factors	**Prospect risk factors**
Presence of reservoir facies	Presence of effective porosity
Presence of mature source rock	Presence of structure
Timing of structuring	Presence of effective seal
	Migration into the structure
	Retention after accumulation

Probability of Discovery

The estimated prospect probability is not the probability of making a discovery but:

The probability of finding at least the minimum quantity of HC estimated in our resource assessment.

Conceptual of the Probability of Geologic Success



Suppose we look at four major factors

- **Hydrocarbon Source**: Hydrocarbons in correct phase and quality were generated.
- •**Reservoir Quality**: Reservoir rock of appropriate permeability and porosity is present.
- •**Geometry**: Geometry of structure is as represented by seismic and slight changes would not jeopardize the accumulation of hydrocarbons.
- •**Seal**: Seal exists with sufficient permeability to retain hydrocarbons.

Probability of Discovery

- The product of major probability factors $P_{disc} = P_{play} \times P_{prospect}$

where $P_{play} = P_{reservoir\ facies} \times P_{mature\ source} \times P_{timing}$

and $P_{prospect} = P_{porosity} \times P_{geometry} \times P_{seal} \times P_{migration} \times P_{retention}$.

- Probability factors are evaluated with respect to presence and effectiveness.

Probability of Regionally Distributed Reservoir Facies

- Describes the probability that a regionally distributed facies that constitute the reservoir interval in the mapped prospects and unmapped resources exist.

Technical tests criteria	Quantitative probability range
Found in all wells in the play area; facies modeling and seismic data clearly indicates presence of the reservoir unit in between wells	0.8 -1.0
Found in at least one well; convincing seismic data clearly indicate a regional distribution of the unit	0.6 - 0.8
Regional distribution of the unit is probable	0.4 - 0.6
Presence is based on analog model	0.2 - 0.4
Reservoir unit not present in the play area	0.0 - 0.2

Probability of Sufficient Mature Source Rock

Describes the probability that a sufficient mature source rock exists.

Technical tests criteria	Quantitative probability range
Commercial production in play area, wells tested moveable HC	0.8 -1.0
Found in at least one well; convincing seismic data clearly indicate a regional distribution of the unit	0.6 - 0.8
Wells in play have HC shows/well samples show presence of source rock & geochemical modeling predicts mature source rock	0.4 - 0.6
Presence is based on analog model	0.2 - 0.4
Presence of mature source rock is probable	0.0 - 0.2

Probability of Timing of Structuring

Describes the probability that the structures have been present before the end of the hydrocarbon generation.

Technical tests criteria	Quantitative probability range
Unambiguous data suggest trap existed before start of migration	0.8 -1.0
Convincing data indicate trap existed before migration	0.6 - 0.8
Based on the available data, it is equally probable that the trap was in existence prior to the end of the HC generation.	0.4 - 0.6
Unconvincing data indicate that the trap was not present prior to the end of the HC generation	0.2 - 0.4
Unambiguous data suggest that the trap was not in existecen priori to the end of HC generation.	0.0 - 0.2

Probability of Effective Porosity

Describes the probability of the existence of an effective reservoir facies with reservoir parameters equal to or higher than the minimum estimate

Technical tests criteria	Quantitative probability range
Identical reservoir rock parameters are found in field or discovery in immediate vicinity	0.8 -1.0
Lateral continuity is probable as indicated by seismic, well, and/or outcrop data	0.6 - 0.8
Existence of effective reservoir parameters is equally probable	0.4 - 0.6
Adequate reservoir parameters may exist in trend	0.2 - 0.4
Reservoir rock has parameters lower than the minimum	0.0 - 0.2

Probability of Structure/Geometric Body

Describes the existence of the mapped structural/geometrical body with a bulk rock volume equal or larger than the minimum value used in the analysis.

Technical tests criteria	Quantitative probability range
Identical structure in immediate vicinity tested successfully	0.8 -1.0
Convincing data indicates probable structure	0.6 - 0.8
A firm conclusion cannot be drawn	0.4 - 0.6
Structure poorly defined by seismic	0.2 - 0.4
Identical structure proven absent	0.0 - 0.2

Probability of Effective Seal

Describes the probability of an efficient top, base and lateral seal of the structure.

Technical tests criteria	Quantitative probability range
Presence of thick, regionally extensive and effective sealing	0.8 -1.0
Same sealing rock unit tested in trend	0.6 - 0.8
Presence of seal is equally probable	0.4 - 0.6
Sealing mechanism poorly defined	0.2 - 0.4
Sealing mechanism proven unsuccessful	0.0 - 0.2

Probability of Migration

Describes the probability of efficient migration of hydrocarbons from the source to the mapped structure.

Technical tests criteria	Quantitative probability range
Unambiguous data verify that HC migrated into similar traps	0.8 -1.0
Trap is situated within a migration pathway	0.6 - 0.8
Available data indicate that it is equally probable that HC have migrated into the trap	0.4 - 0.6
Migration path is complicated and tortuous	0.2 - 0.4
Trap is not within a migration pathway	0.0 - 0.2

Probability of Retention after Accumulation

Evaluates reactivation of faults, regional uplift and tilting after accumulation

Technical tests criteria	Quantitative probability range
No indication of tectonic movement after accumulation	0.8 -1.0
Overlying sediments were eroded after accumulation	0.6 - 0.8
Equally probable that the trap has been or has not been affected by tectonic movements after accumulation	0.4 - 0.6
Sealing mechanism after accumulation is poorly defined	0.2 - 0.4
Trap has experienced disturbances by tectonic movements	0.0 - 0.2

Play Probability

Confirmed play

- Probability (P) is 1
- Tested and flowed HC to the surface (technical discovery)
- Example:

Play risk factors	Probability (Play)
Presence of reservoir facies	1.0
Presence of mature source rock	1.0
Timing of structuring	1.0
Marginal play probability	**1.0**

Marginal play probability = 1.0 x 1.0 x 1.0

Play Probability

Unconfirmed play

- Probability is between 0 and 1
- Play is not drilled yet or play has no technical discovery
- Example:

Play risk factors	Probability (Play)
Presence of reservoir facies	1.0
Presence of mature source rock	0.9
Timing of structuring	1.0
Marginal play probability	**0.9**

Marginal play probability = 1.0 x 0.9 x 1.0

Prospect Probability

Conditional probability

- The chance that the prospect will be an accumulation on the condition that the play is favorable to hydrocarbon accumulation (GeoX)

Prospect risk factors	Probability (Prospect|Play)
Presence of effective porosity	0.8
Presence of structure	0.8
Presence of effective seal	1.0
Migration into the structure	0.8
Retention after accumulation	1.0
Conditional prospect probability	**0.512**

Conditional prospect probability = 0.8 x 0.8 x 1.0 x 0.8 x 1.0

Probability of Success

- Probability of success = Pplay * Pprospect

PROSPECT WHOSE PLAY IS CONFIRMED	Probability
Marginal play probability	1.0
Conditional prospect probability	0.512
Unconditional probability	0.512
Dry hole risk	0.488

PROSPECT WHOSE PLAY IS NOT CONFIRMED	Probability
Marginal play probability	0.9
Conditional prospect probability	0.512
Unconditional probability	0.46
Dry hole risk	0.54

Unconditional probability = 1.0 x 0.512

Dry hole risk = 1 – 0.512

Unconditional probability = 0.9 x 0.512

Dry hole risk = 1 – 0.46

Application of POS to Expected Monetary Value (EMV)

Expected Monetary Value (EMV)

- EMV=(R*POS)-(RC*(1-POS))
  - EMV=Expected Monetary Value
  - R = Reward = Net Present Value (NPV)
  - POS= Probability of Success
  - RC= Risk Capital = Bonuses, Dry Hole Cost, G&G etc.

Probability of Success (POS): Geological Risk only

Probability of success = 0.50

This is the typical probability of success of a step out or delineation well, or of an adjoining structure

Probability of success = 0.20 - 0.30

This is the typical range of probability of success of exploration in an area with many similar plays and structures and for and exploration well which is in such a structure not too far from existing discoveries

Probability of success = 0.10 - 0.20

This is the typical range of probability of success of exploration in a well explored area with a variety of different plays and on a new location

Probability of success = 0.02 - 0.05

This is the typical range of probability of success of exploration in a poorly explored area or a new geological basin in which previously no wells have been drilled or only dry holes have been drilled

Total Probability of Success (POS)

- $POS = P_{expl.} * P_{dev.} * P_{fiscal} * P_{pol.} * P_{econ.}$
- Example:
  - POS = 0.5*0.9*1.0*0.8*0.6
  - POS = 0.22

EMV Example

- Assumptions
- NPV = 120 million USD
- RC = 15 million USD
- POS = 22%

- EMV = (R*POS) - (RC*(1-POS))
- EMV = (120*0.22) - (15*(1-0.22))
- EMV = 26.4 – 11.7
- EMV = 14.7million USD

  - Break-even POS = RC/(NPV+RC)
  - Break-even POS = 15/(120+15)
  - Break even POS = 11.1% (EMV=0)

Success Capacity

How many dry wells can a discovery carry?

Success Capacity = (1/break-even success ratio) - 1

Example:

Success Capacity = (1/0.111) - 1
Success Capacity = 8

One success well can carry 8 dry wells and still have a positive NPV

Table Form for EMV Calculation

	Capital	POS	EMV
Outcome 1	120	22.0 %	26.4
1-POS	-15	78.0 %	-11.7
Total EMV			14.7

Break-even POS	11.1 %

Success Capacity	8.0

Probability of One Success

What number of wells would be needed to be sure of at least one discovery at a certain confidence level

The probability of at least one success	=	1 - the probability of all failures

$$CL = 1-(1-POS)^n$$

CL = Desired confidence level
POS = Success probability
1-POS = probability of failure
n = No. of Exploration wells

Combined Probability of Success