# Risk vs reward?

# When to explore beyond the proven fairway?

**Dave Quirk*, MGS Energy**

**Introduction**

**Play openers**

**What do historical statistics tell us?**

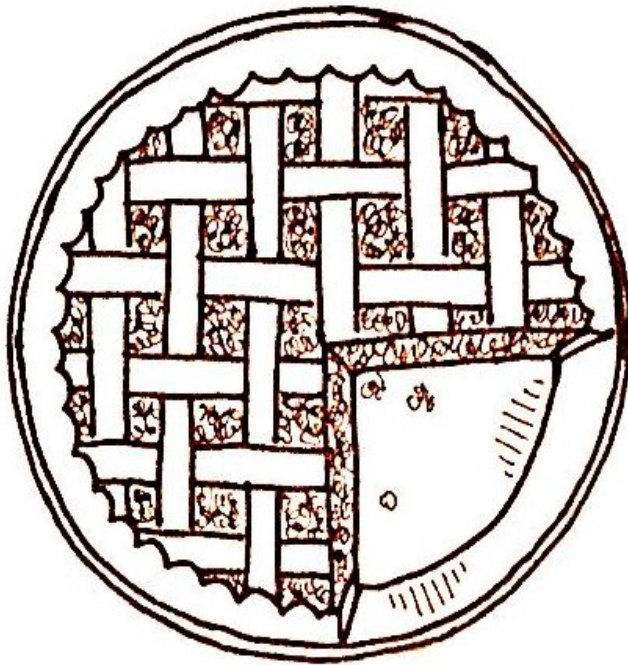**Historical example of exploring a world class play**

**Ways of identifying new potential**

**Conclusions**

**Predicting future discoveries**

* dgquirk@outlook.com

Amalie Quirk, 2018

# Introduction

# Once a part play is proven...

- The chance of making another discovery is generally good...

- ...and, assuming the part play boundaries are defined correctly...

- The chance of finding reservoir, seal & charge is predictable

- **But average size of discov̶ decreases significantly ove̶**

**Proven Part Play**

Chance of discovery =
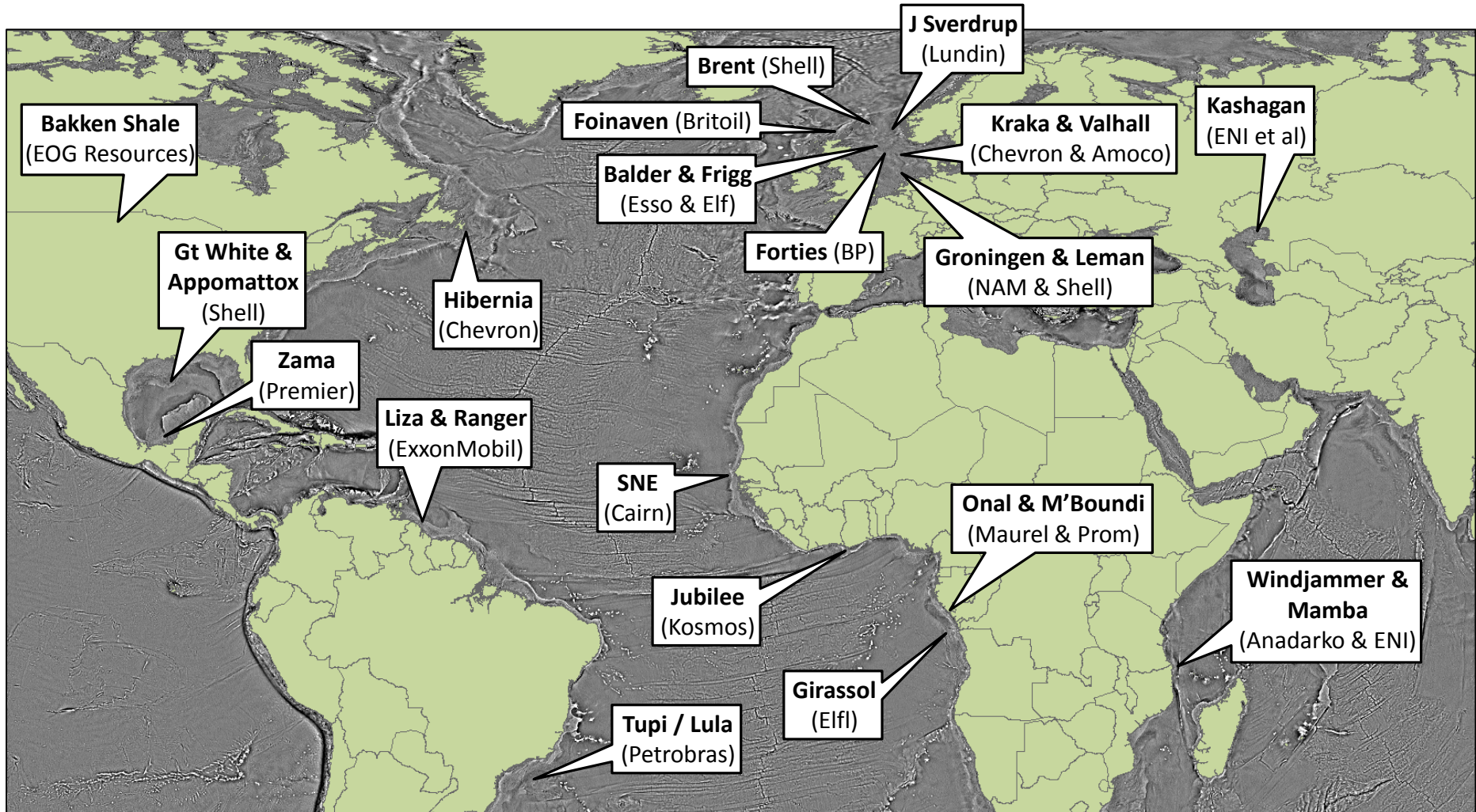Av Prospect Risk (PoSg)
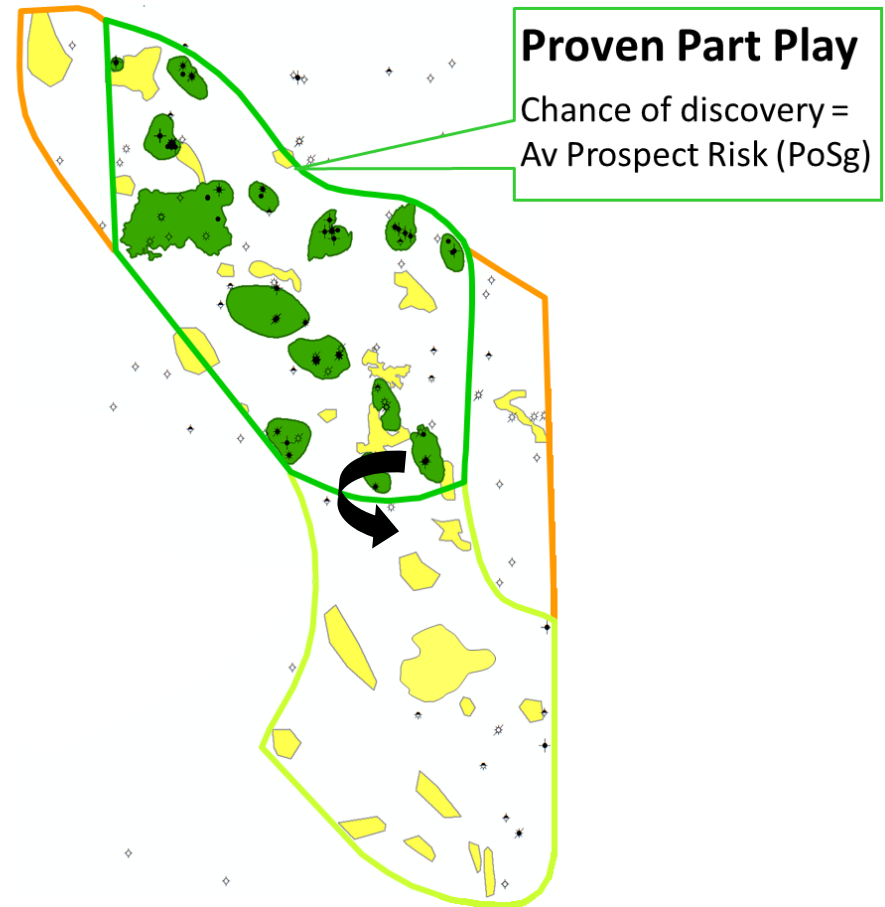
# Discovery sequence Campos offshore, all plays
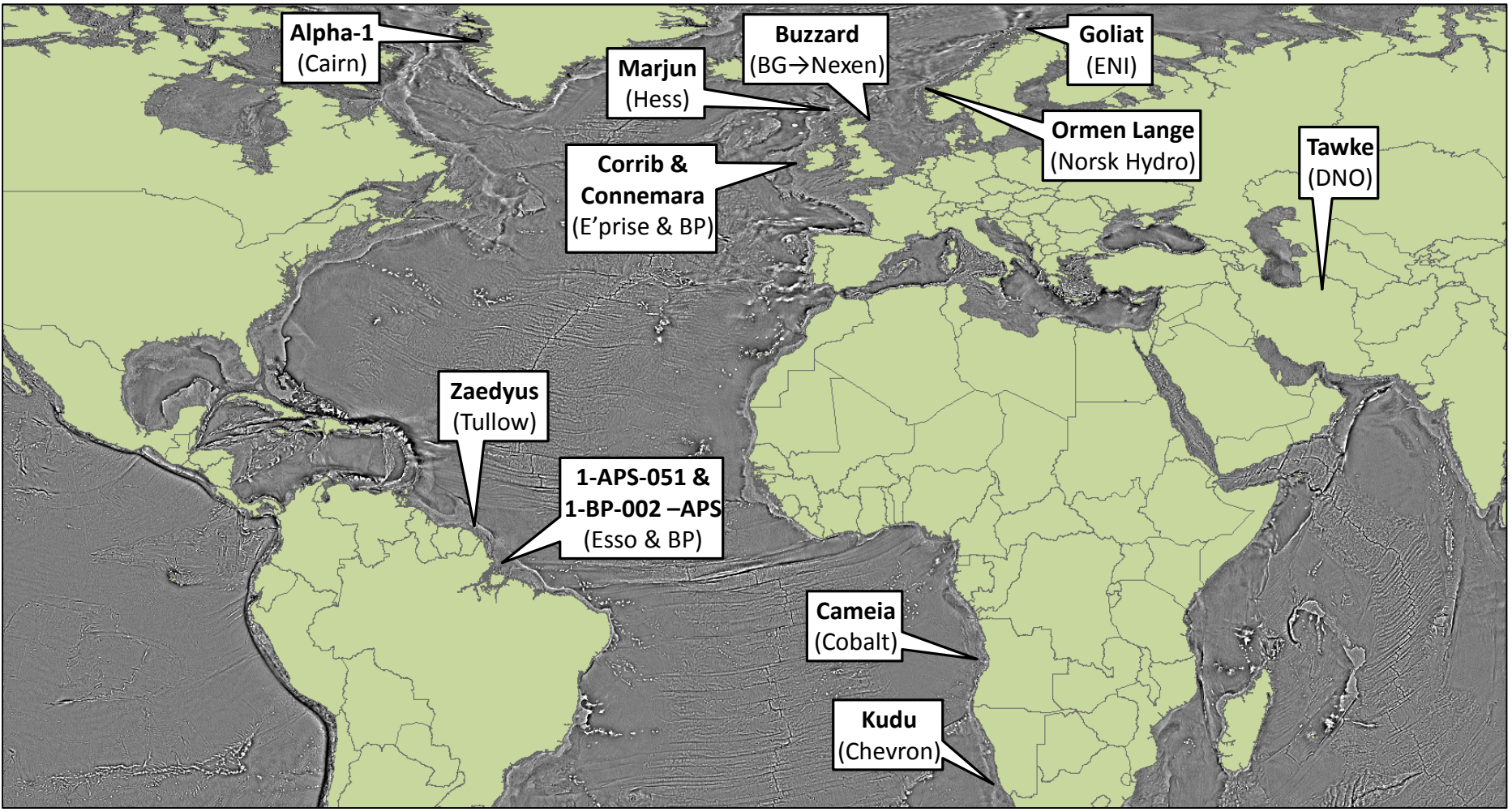
**32 billion boe (why here?)**

**Steps in creaming curve come from proving new part play (after crossing boundary)**

# Play openers

# Play openers that caught the headlines



**J Sverdrup** (Lundin)

**Brent** (Shell)

**Bakken Shale** (EOG Resources)

**Foinaven** (Britoil)

**Kraka & Valhall** (Chevron & Amoco)

**Kashagan** (ENI et al)

**Balder & Frigg** (Esso & Elf)

**Gt White & Appomattox** (Shell)

**Forties** (BP)

**Groningen & Leman** (NAM & Shell)

**Hibernia** (Chevron)

**Zama** (Premier)

**Liza & Ranger** (ExxonMobil)

**SNE** (Cairn)

**Onal & M'Boundi** (Maurel & Prom)

**Jubilee** (Kosmos)

**Windjammer & Mamba** (Anadarko & ENI)

**Girassol** (Elfl)

**Tupi / Lula** (Petrobras)

# Some discoveries with disappointing follow-ons (so far)



Alpha-1 (Cairn)

Marjun (Hess)

Buzzard (BG→Nexen)

Goliat (ENI)

Ormen Lange (Norsk Hydro)

Tawke (DNO)

Corrib & Connemara (E'prise & BP)

Zaedyus (Tullow)

1-APS-051 & 1-BP-002 −APS (Esso & BP)

Cameia (Cobalt)

Kudu (Chevron)

# Recent examples of resource found in part plays



Egersund Basin
180 MMboe

Siri Canyon
200 MMboe

Barmer Basin
1050 MMboe

Norphlet play
c.1200 MMboe

E Breaks Mio-Plio
650 MMboe

Lokichar Basin
640 MMboe

Tano Basin Ce-Tu
2500 MMboe

SEAL deepwater
c.1200 MMboe
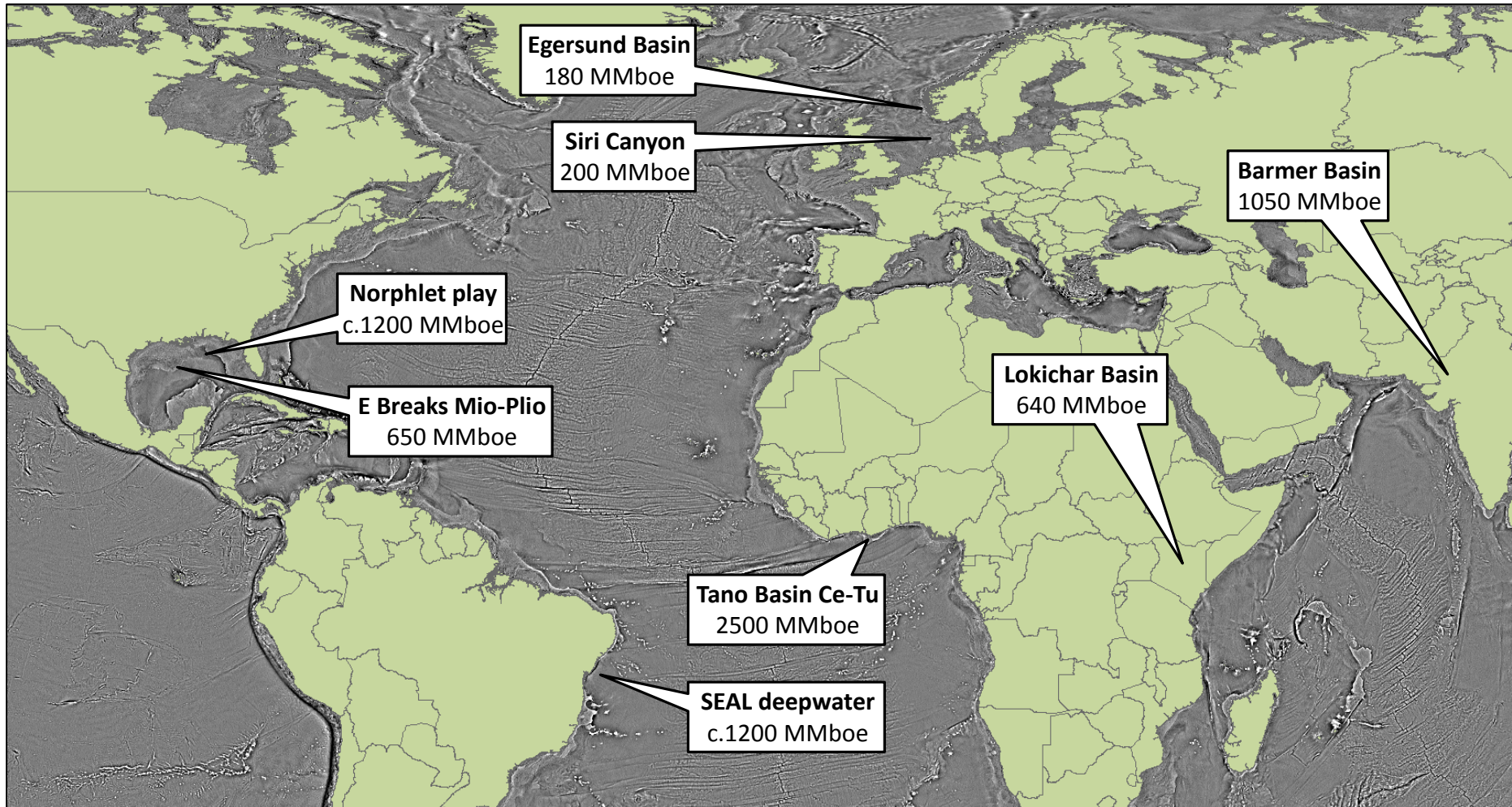
Guyana, Mauritania-Senegal & many North Sea plays are exceptions

# Recent examples of resource found in part plays

| richness of play | MMboe per 1000 km$^2$ | example plays |
|---|---|---|
| Super-Rich | 1000-2000 | Middle East JU Arab Lst, Denmark KU Chalk |
| Rich | 500-1000 | BR Santos Apt Pre-Salt, AO LCF Miocene turbidites |
| Moderate | 100-500 | US GoM Mio-Pliocene, Hammerfest Basin Tr ssts |
| Low | <100 | IQ Kur Triassic carbonates, Algeria Lwr Paleozoic ssts |

from Quirk et al. 2017. Yet-to-find in play analysis. Journal of Petroleum Geology, 40, 217-48
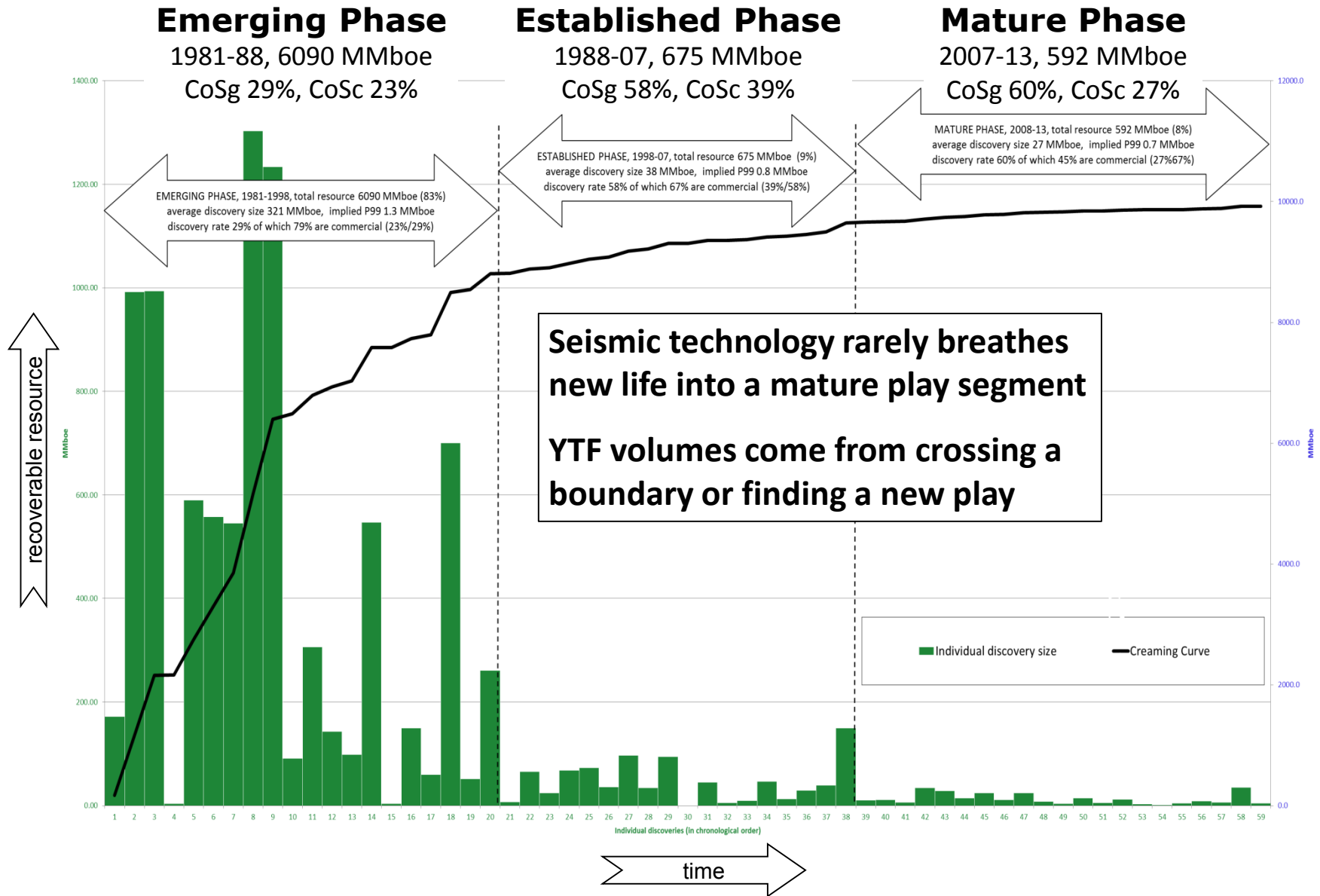
# What do historical statistics tell us?

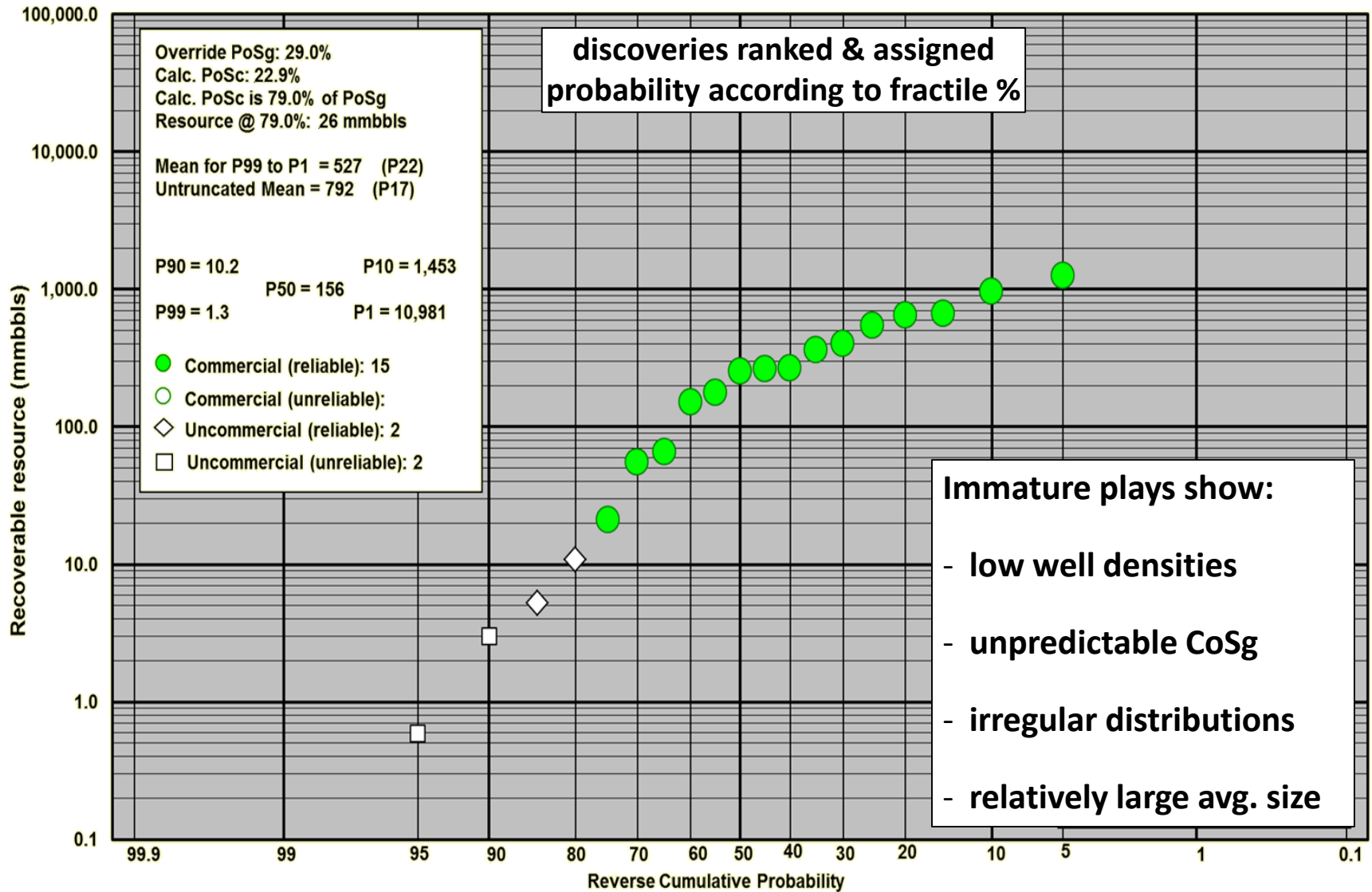# Prospect column heights are not lognormal...

# ...but discovery size distributions are (thank goodness)
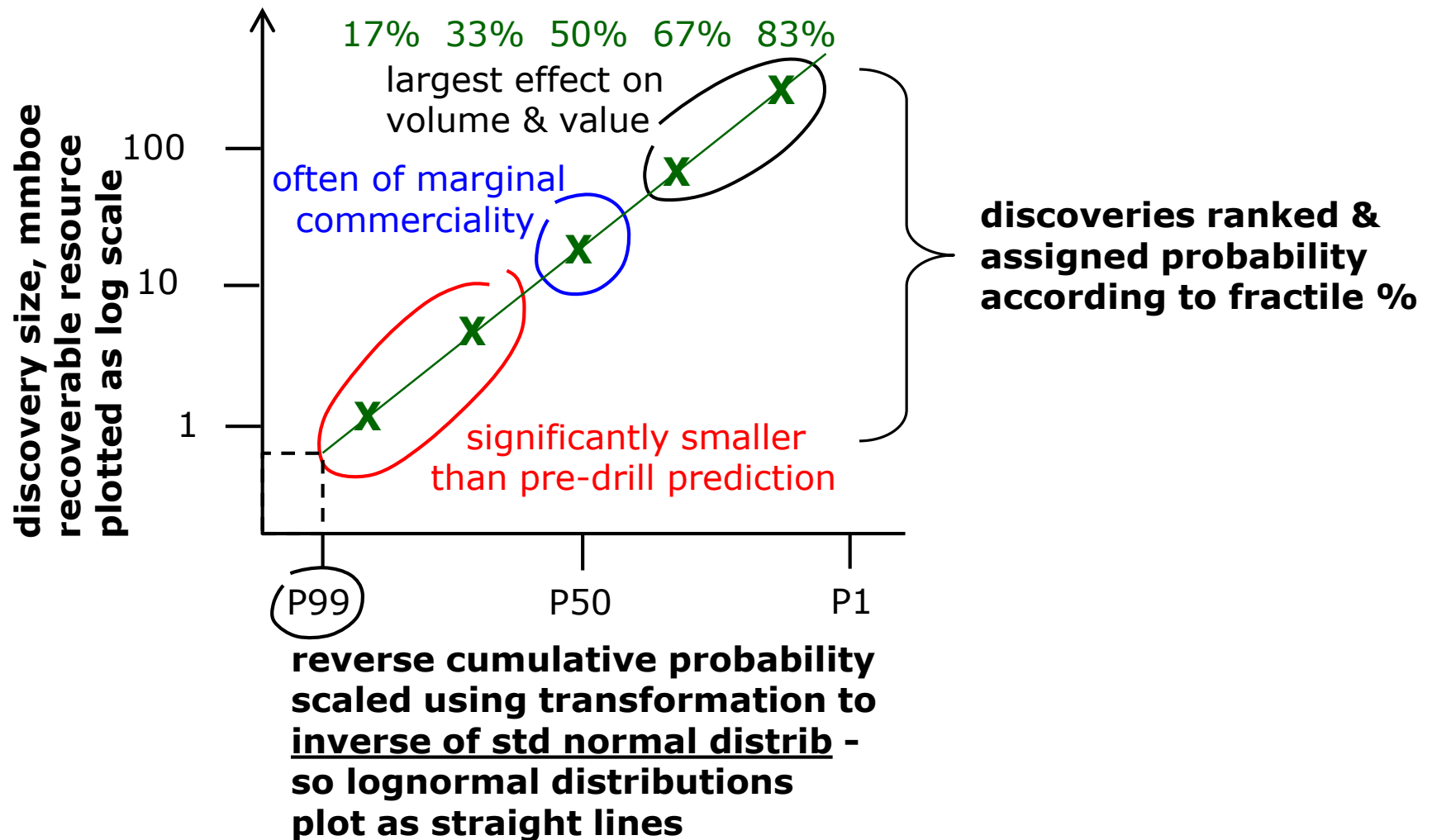
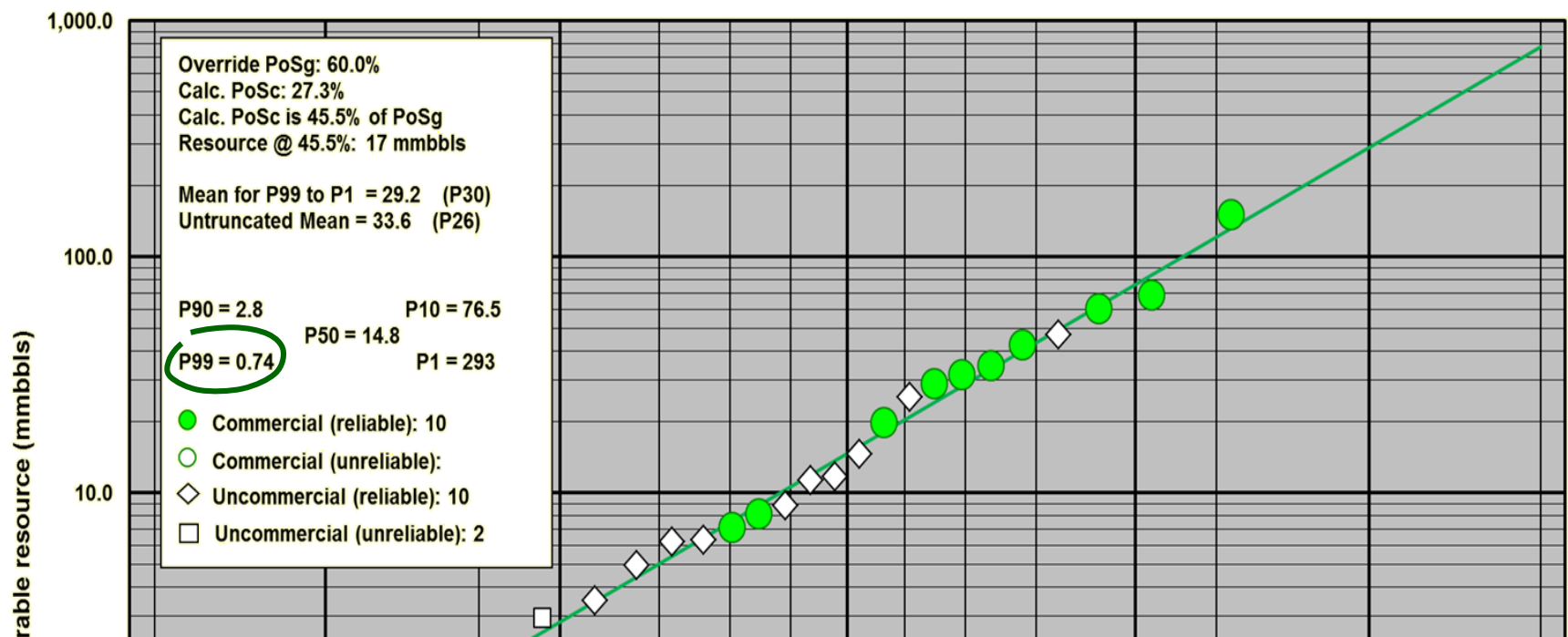# Change in maturity of syn-rift Jurassic play in Haltenbank Platform



**Emerging Phase**
1981-88, 6090 MMboe
CoSg 29%, CoSc 23%

**Established Phase**
1988-07, 675 MMboe
CoSg 58%, CoSc 39%

**Mature Phase**
2007-13, 592 MMboe
CoSg 60%, CoSc 27%

EMERGING PHASE, 1981-1998, total resource 6090 MMboe (83%) average discovery size 321 MMboe, implied P99 1.3 MMboe discovery rate 29% of which 79% are commercial (23%/29%)

ESTABLISHED PHASE, 1998-07, total resource 675 MMboe (9%) average discovery size 38 MMboe, implied P99 0.8 MMboe discovery rate 58% of which 67% are commercial (39%/58%)

MATURE PHASE, 2008-13, total resource 592 MMboe (8%) average discovery size 27 MMboe, implied P99 0.7 MMboe discovery rate 60% of which 45% are commercial (27%67%)

**Seismic technology rarely breathes new life into a mature play segment**

**YTF volumes come from crossing a boundary or finding a new play**

recoverable resource

Individual discovery size — Creaming Curve

Individual discoveries (in chronological order)

time

# Emerging phase – 1981-98 – total 6090 MMboe found:
# 19 discoveries, avg size 321 MMboe, PoSg 29%, 79% commercial

discoveries ranked & assigned
probability according to fractile %

Override PoSg: 29.0%
Calc. PoSc: 22.9%
Calc. PoSc is 79.0% of PoSg
Resource @ 79.0%: 26 mmbbls

Mean for P99 to P1 = 527   (P22)
Untruncated Mean = 792   (P17)

P90 = 10.2                P10 = 1,453
            P50 = 156
P99 = 1.3                 P1 = 10,981

● Commercial (reliable): 15
○ Commercial (unreliable):
◇ Uncommercial (reliable): 2
□ Uncommercial (unreliable): 2

Recoverable resource (mmbbls)

Reverse Cumulative Probability

**Immature plays show:**

- **low well densities**

- **unpredictable CoSg**

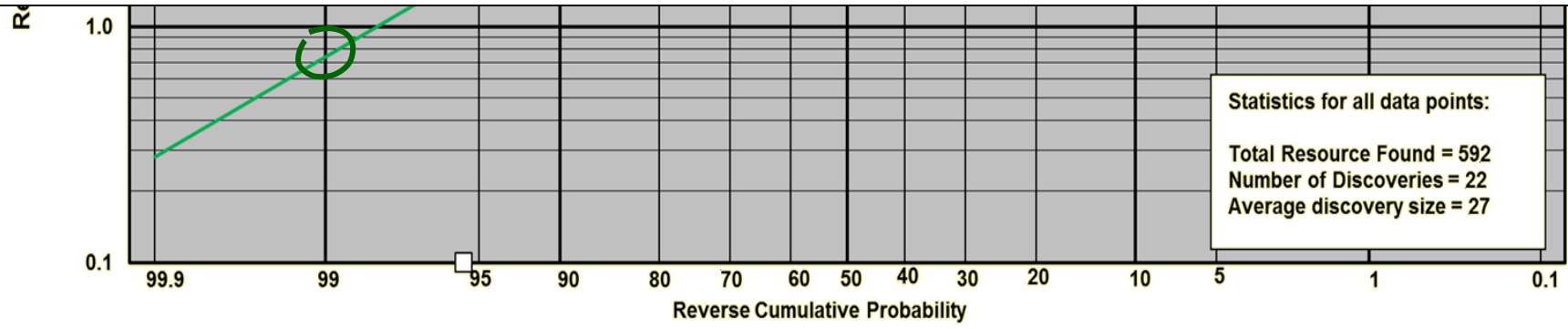- **irregular distributions**

- **relatively large avg. size**

# Established phase – 1998-2007 – total 675 MMboe found: 18 discoveries, avg size 38 MMboe, CoSg 58% (67% commercial)
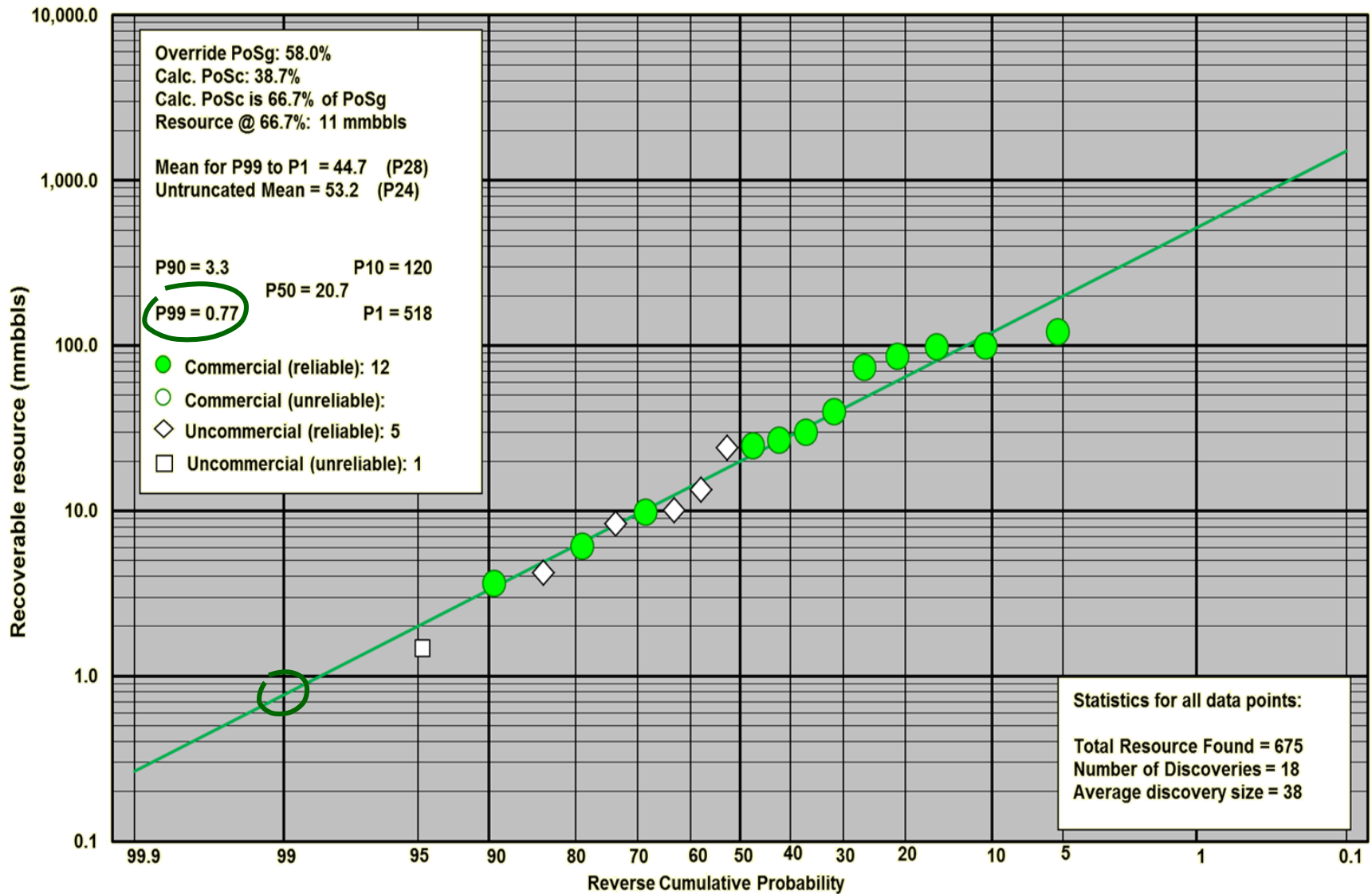
# Mature phase – 2008-13 – 592 MMboe found:
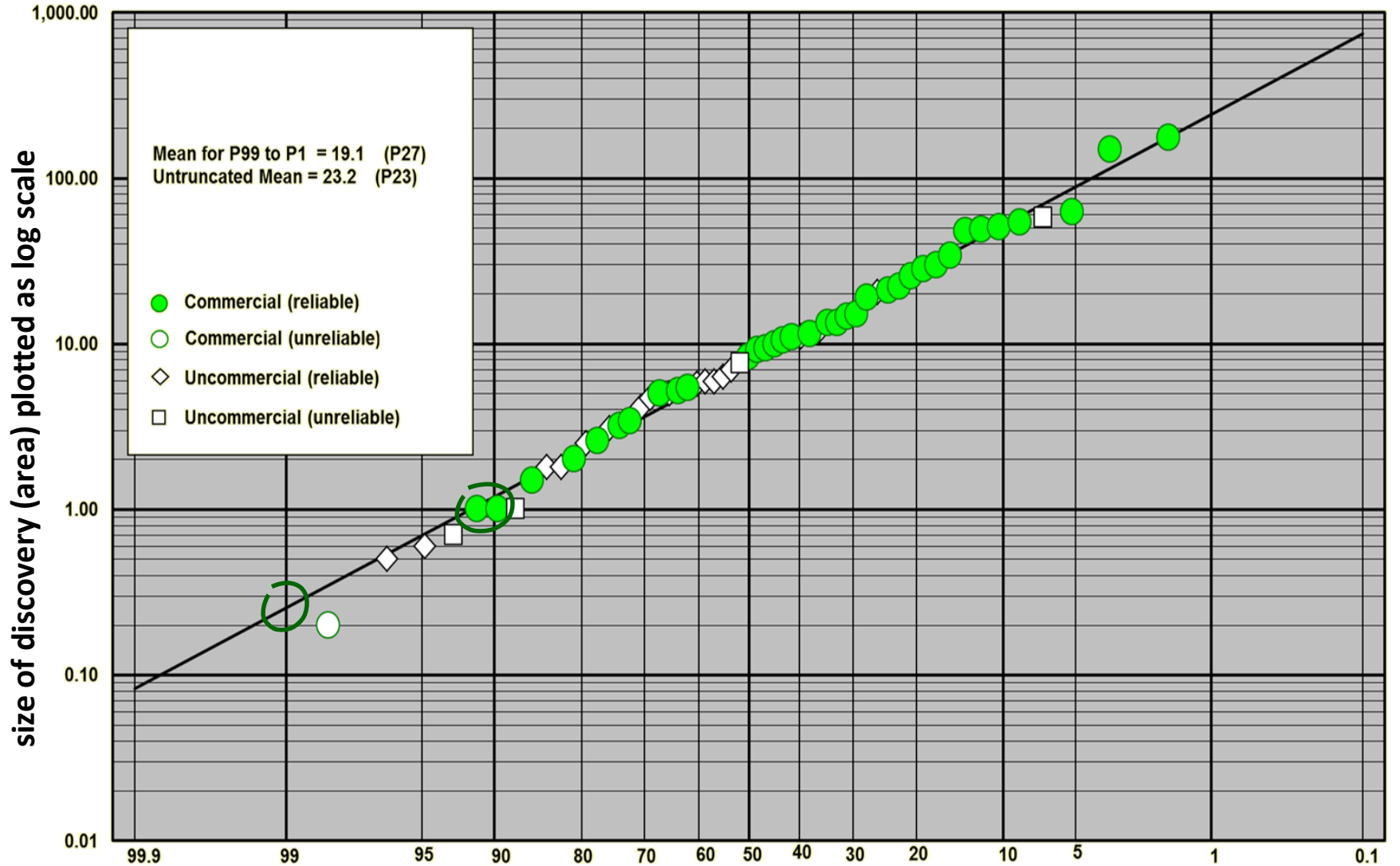# 22 discoveries, avg size 27 mmboe, CoSg 60% (45% commercial)



Override PoSg: 60.0%
Calc. PoSc: 27.3%
Calc. PoSc is 45.5% of PoSg
Resource @ 45.5%: 17 mmbbls

Mean for P99 to P1 = 29.2 (P30)
Untruncated Mean = 33.6 (P26)

P90 = 2.8          P10 = 76.5
        P50 = 14.8
P99 = 0.74              P1 = 293

● Commercial (reliable): 10
○ Commercial (unreliable):
◇ Uncommercial (reliable): 10
□ Uncommercial (unreliable): 2

**Small discoveries are usually due to smaller-than-mapped container (+/- limited reservoir)**

Statistics for all data points:

Total Resource Found = 592
Number of Discoveries = 22
Average discovery size = 27

y-axis: Recoverable resource (mmbbls)
x-axis: Reverse Cumulative Probability

# Distribution of footprint areas in km² for Haltenbank Jurassic play

# Rec. resource vs footprint area for Haltenbank Jurassic play
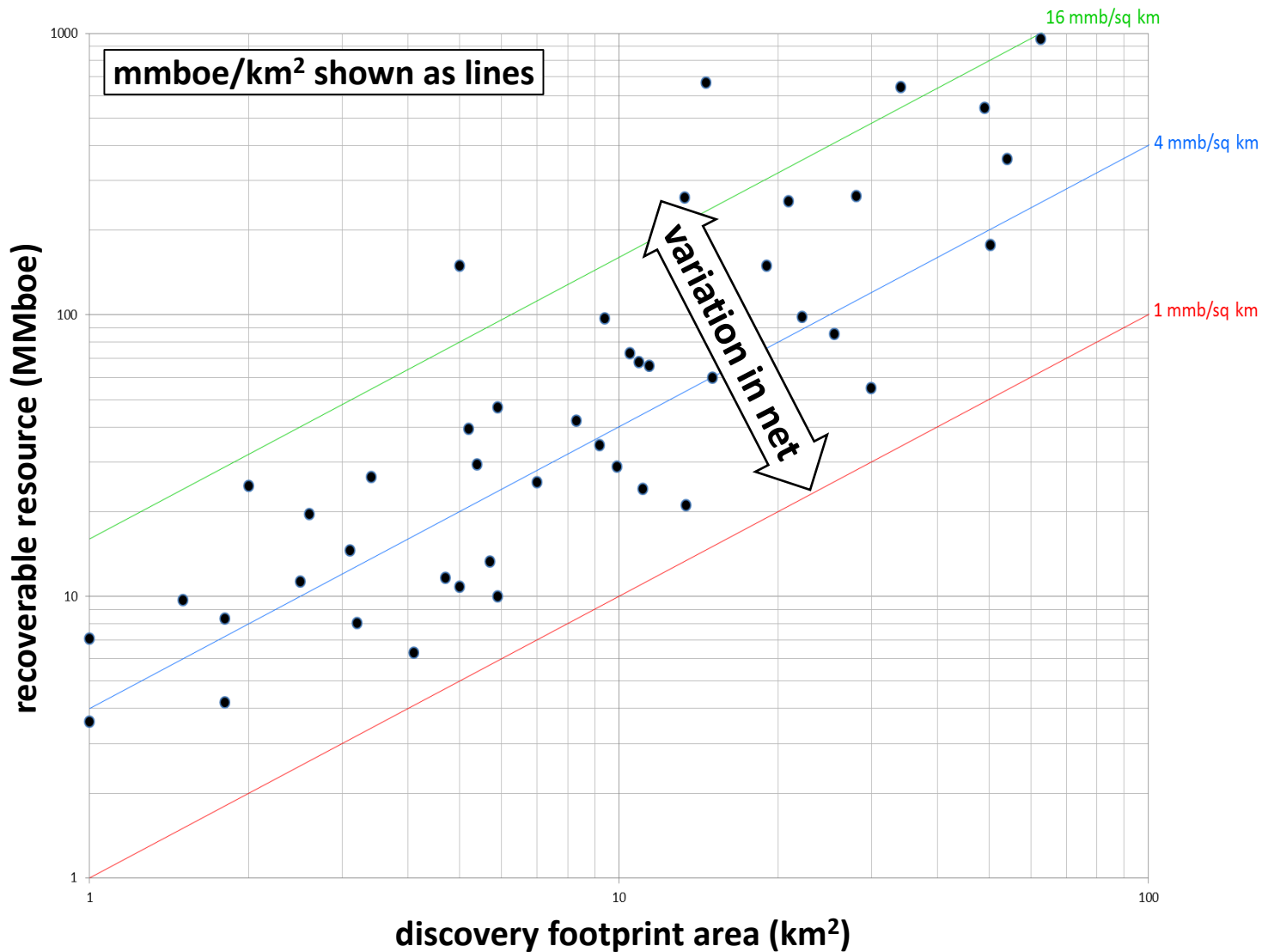
# Equivalent pay in Haltenbank Jurassic play (i.e. 1 km² around well)

| | | |
|---|---|---|
| 1000000 | 1.0 | |
| 4.7 | | |
| 0.114 | | |
| 0.65 | | |
| 0.30 | | |
| 0.80 | | |
| 0.80 | | |
| | | |
| **0.42** | | |

| | | |
|---|---|---|
| 1000000 | 1.0 | |
| 16.0 | | |
| 0.214 | | |
| 0.75 | | |
| 0.40 | | |
| 0.85 | | |
| shape factor | 0.85 | |
| | | |
| **4.7** | | |

| | | |
|---|---|---|
| 1000000 | 1.0 | |
| 78.3 | | |
| 0.31 | | |
| 0.85 | | |
| 0.50 | | |
| 0.90 | | |
| 0.90 | | |
| | | |
| **53.1** | | |

# Historical discovery rate (CoSg) in single & multiple plays
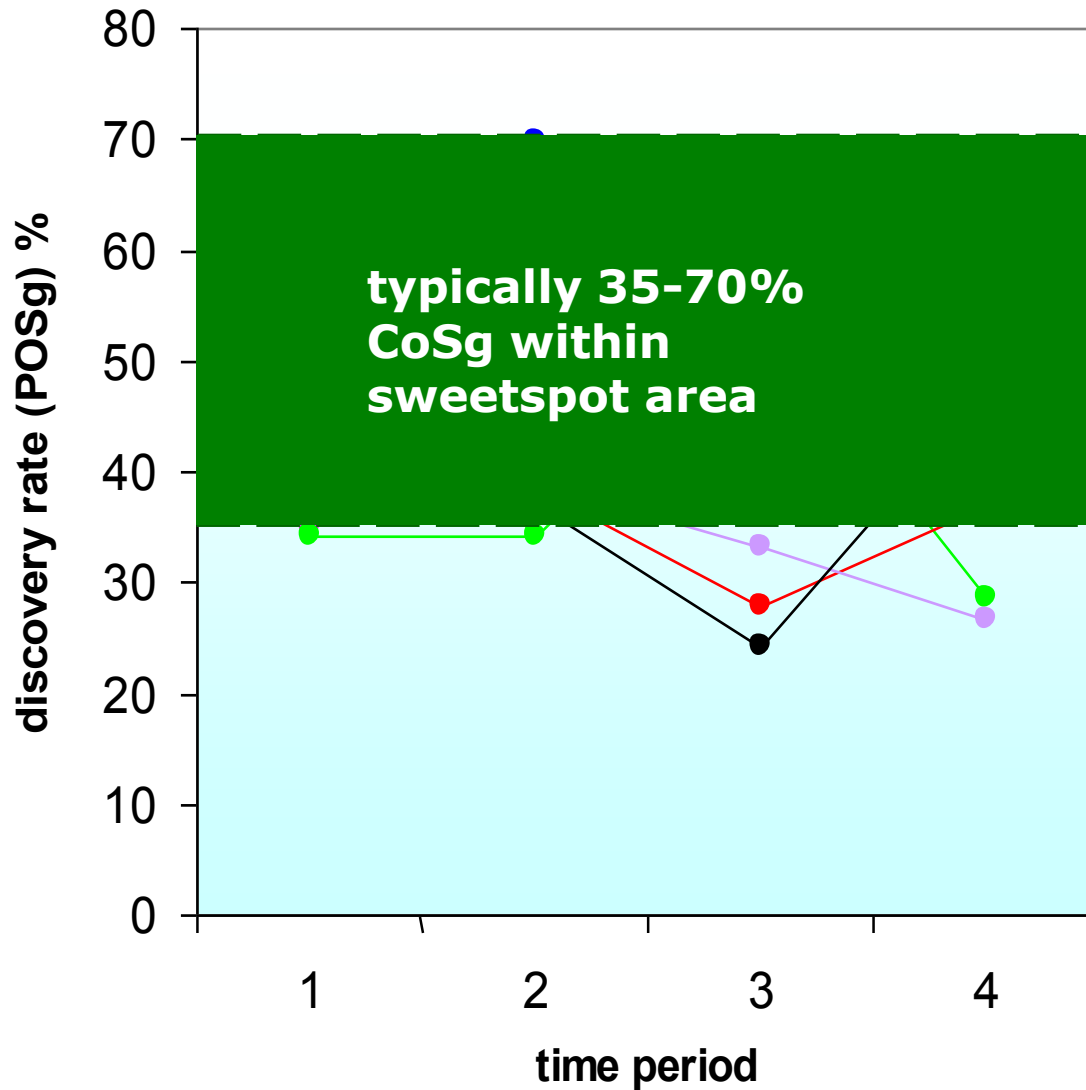


**typically 35-70% CoSg within sweetspot area**

y-axis: discovery rate (POSg) %

x-axis: time period

**Nature seems to present a relatively consistent chance of encountering all 4 elements of an oil/gas accumulation - charge, reservoir, seal, container - with typically one key risk.**
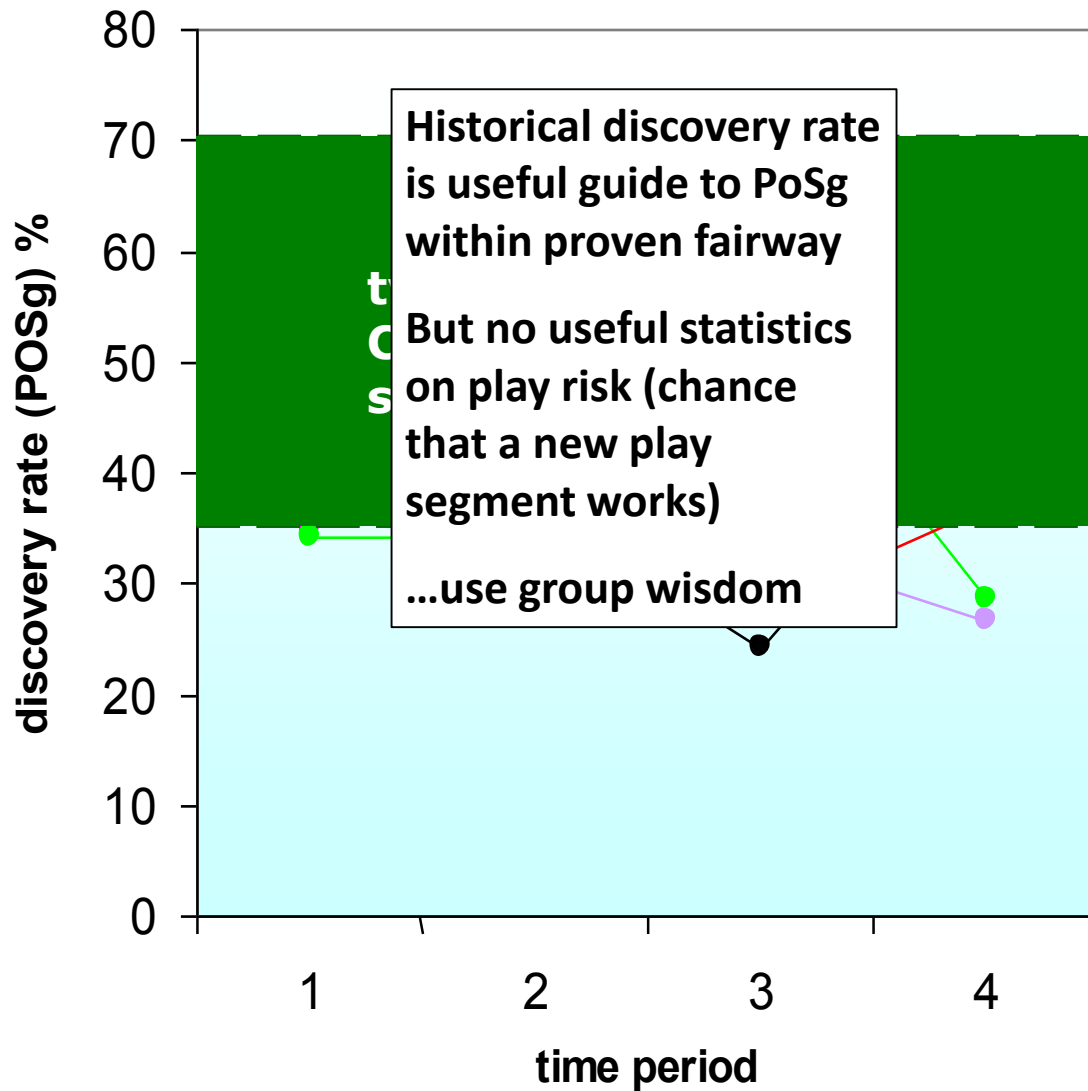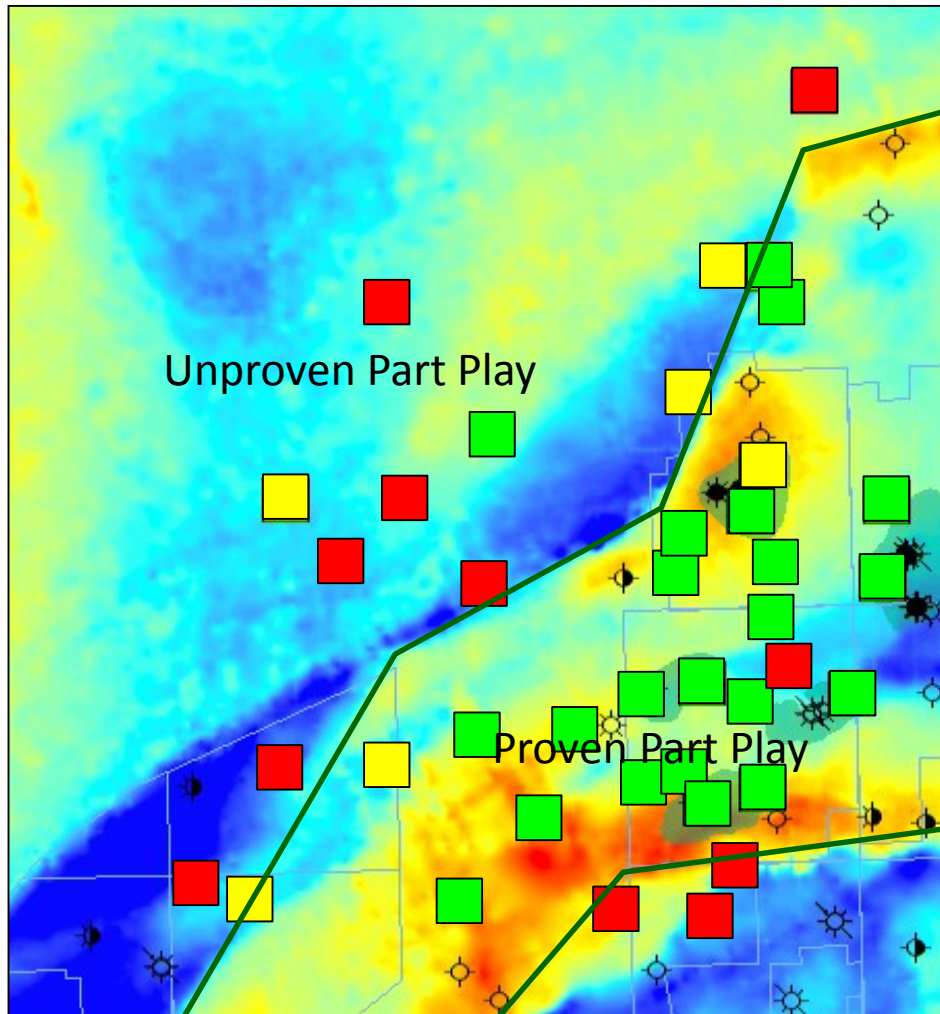
**Is CoSg an inherent property of each basin / main play?**

**But need to define boundaries of sweetspot.**

**After first discovery, CoSg tends to be >50%, except in poorly imaged plays**

Quirk & Ruthrauff, 2008. Toward consistency in petroleum exploration. AAPG Bulletin, 92

# Historical discovery rate (CoSg) in single & multiple plays



**discovery rate (POSg) %**

**time period**

Historical discovery rate is useful guide to PoSg within proven fairway

But no useful statistics on play risk (chance that a new play segment works)

...use group wisdom

Nature seems to present a relatively consistent chance of encountering all 4 elements of an oil/gas accumulation - charge, reservoir, seal, container - with typically one key risk.

Is CoSg an inherent property of each basin / main play?

But need to define boundaries of sweetspot.

After first discovery, CoSg tends to be >50%, except in poorly imaged plays

Quirk & Ruthrauff, 2008. Toward consistency in petroleum exploration. AAPG Bulletin, 92

# To assess chance of finding reservoir, seal, trap & charge use well traffic lights (not GDE interpretations) + seismic



Unproven Part Play

Proven Part Play

Green = effective reservoir present, Yellow = uncertain, Red = reservoir absent
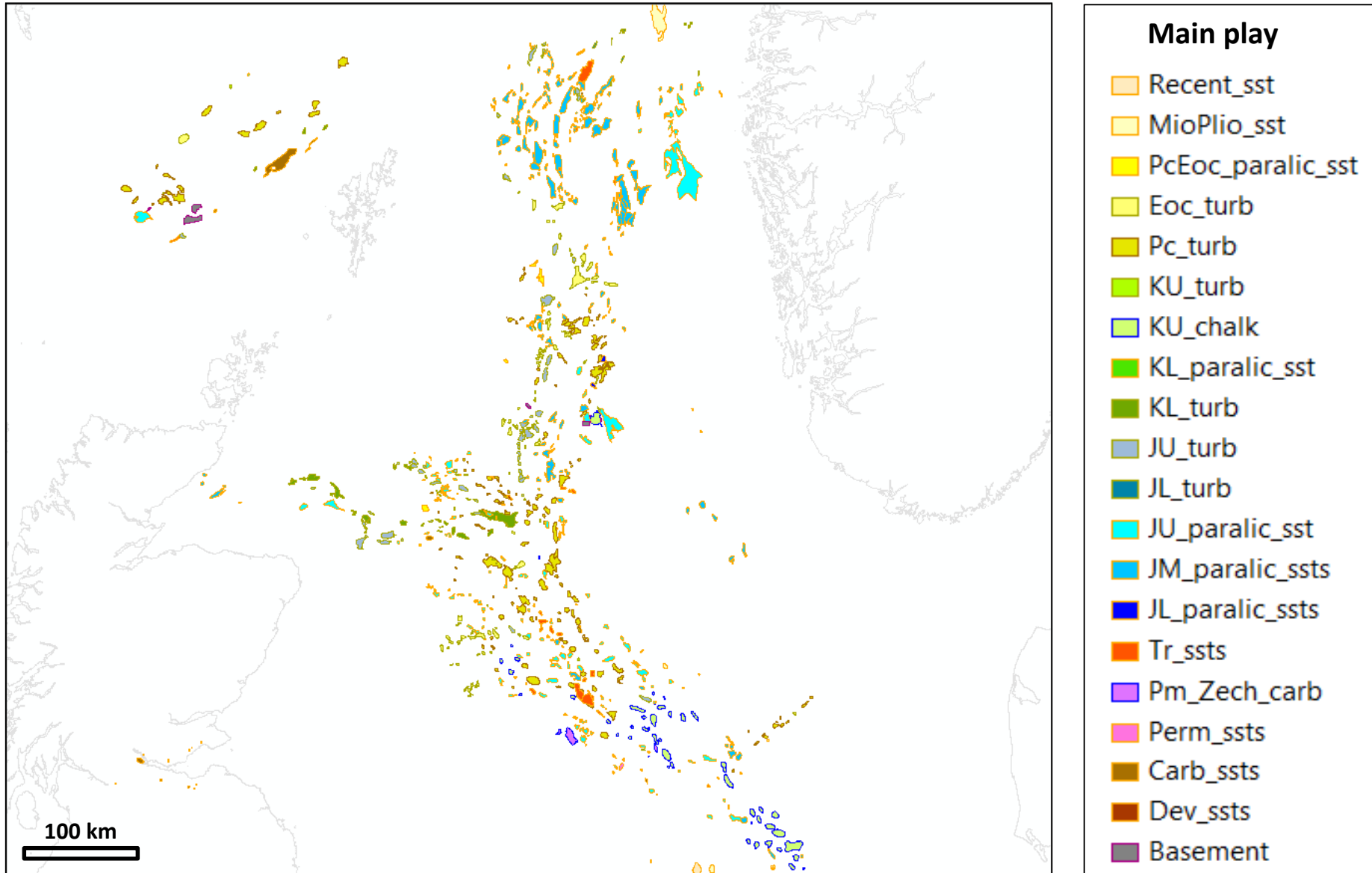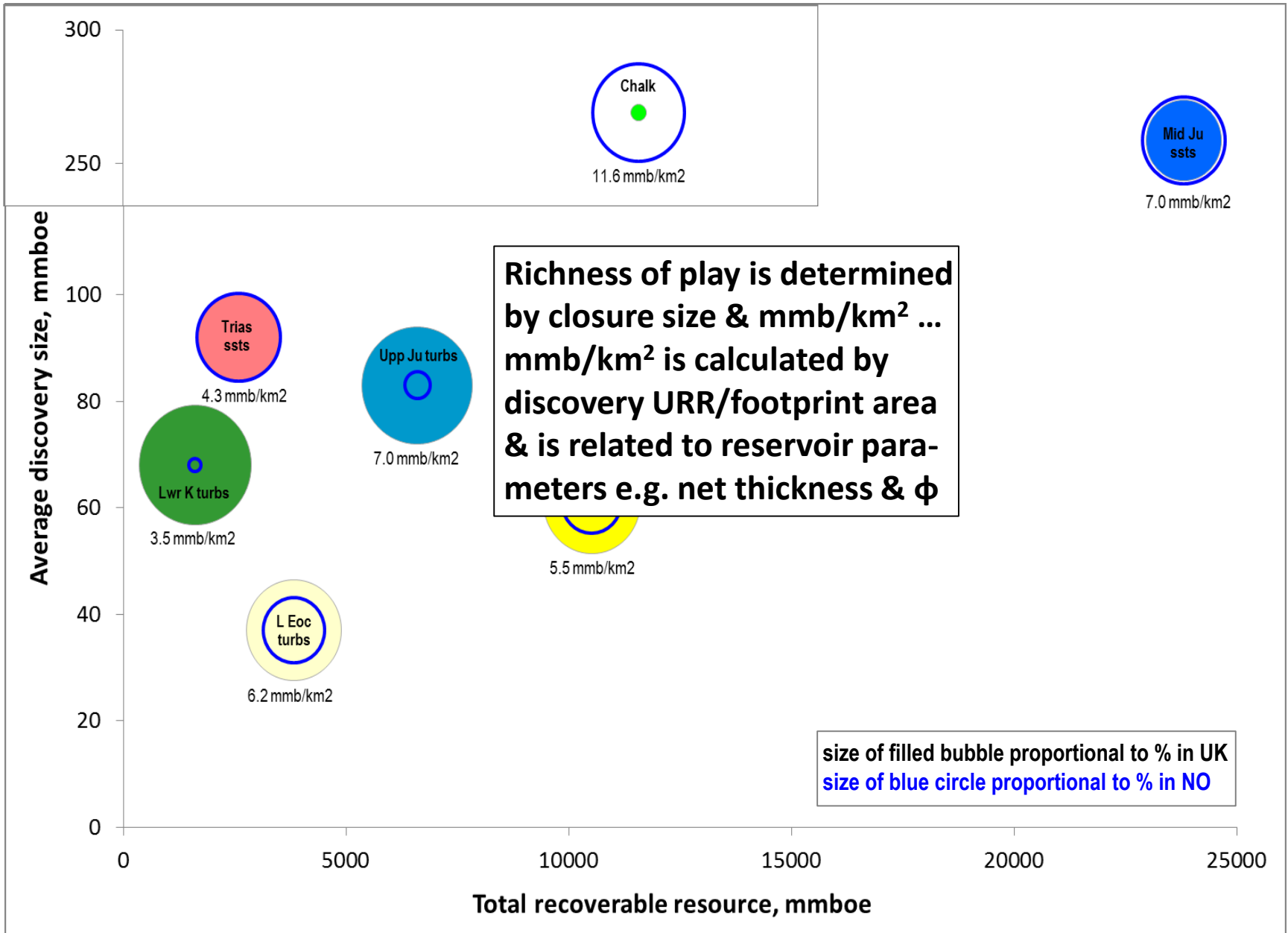Background grid is thickness of play interval (orange-yellow = thin, blue = thick)

Key geological boundaries define part plays / play segments - generally visible on seismic but can be delineated with structural elements, thickness maps, well traffic lights & play-coded discoveries ...but are these remain interpretations ...& need to be kept evergreen.

Draw boundaries with as few vertices as possible – to reflect uncertainty & to allow easy updating

# Historical example of exploring a world class play

# Play-coded discoveries in North Sea (c.78 part plays, excl. SNS)



**Main play**

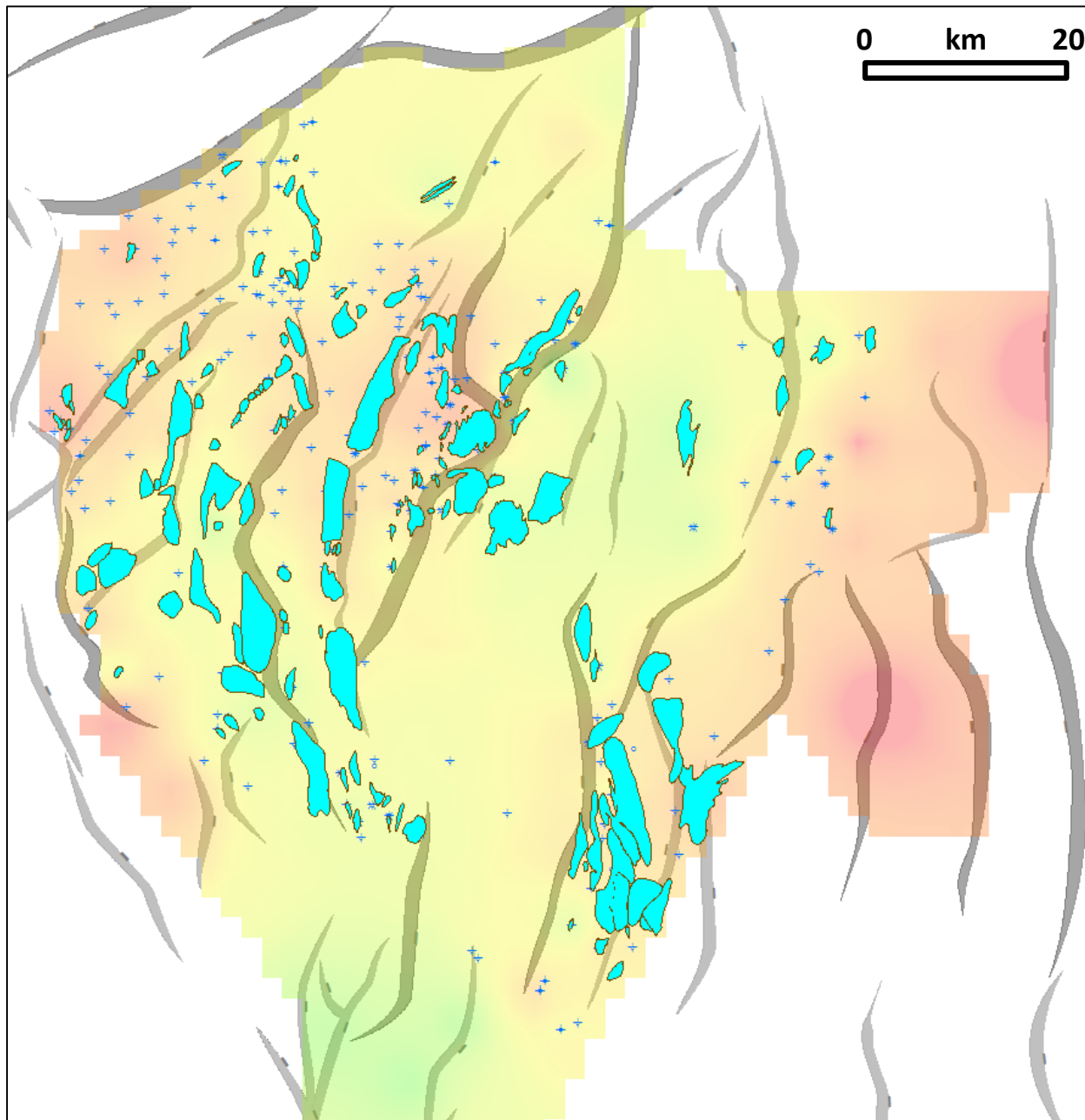- Recent_sst
- MioPlio_sst
- PcEoc_paralic_sst
- Eoc_turb
- Pc_turb
- KU_turb
- KU_chalk
- KL_paralic_sst
- KL_turb
- JU_turb
- JL_turb
- JU_paralic_sst
- JM_paralic_ssts
- JL_paralic_ssts
- Tr_ssts
- Pm_Zech_carb
- Perm_ssts
- Carb_ssts
- Dev_ssts
- Basement

100 km

# Total resource found & avg discovery size in main N Sea plays



size of filled bubble proportional to % in UK
size of blue circle proportional to % in NO

Richness of play is determined by closure size & mmb/km² … mmb/km² is calculated by discovery URR/footprint area & is related to reservoir parameters e.g. net thickness & φ
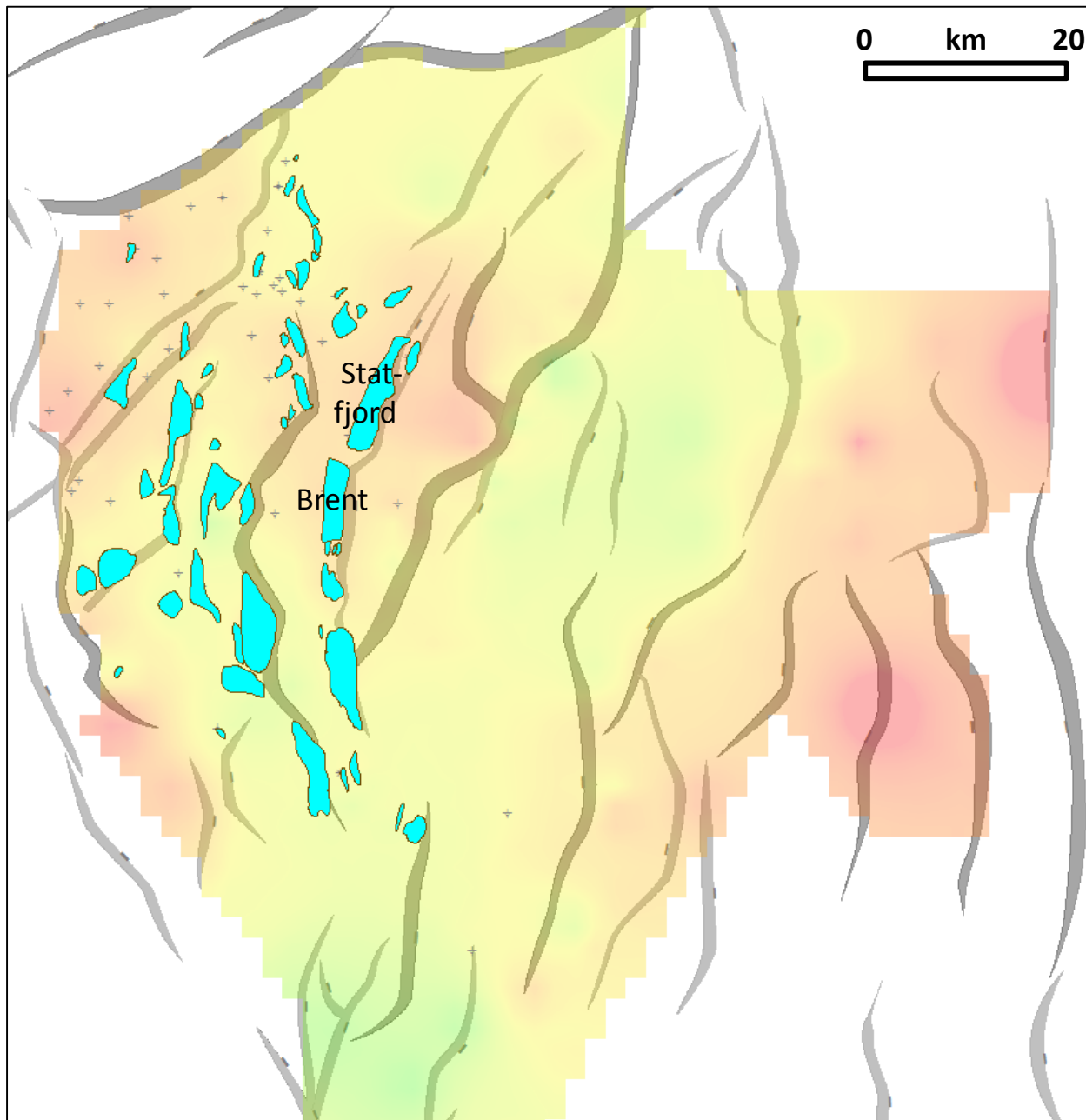
# Brent JU paralic sst, North Viking part play – discovery sequence
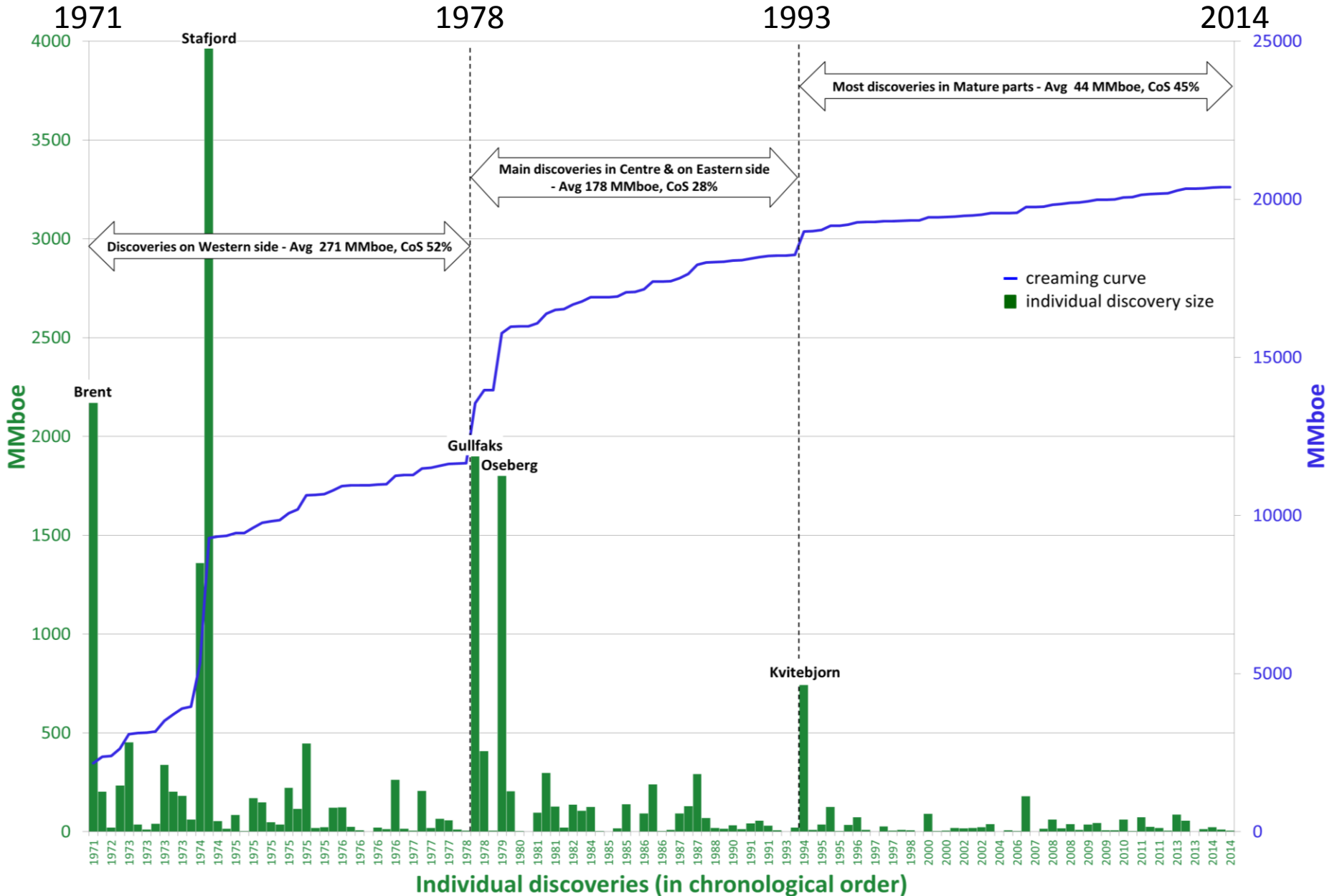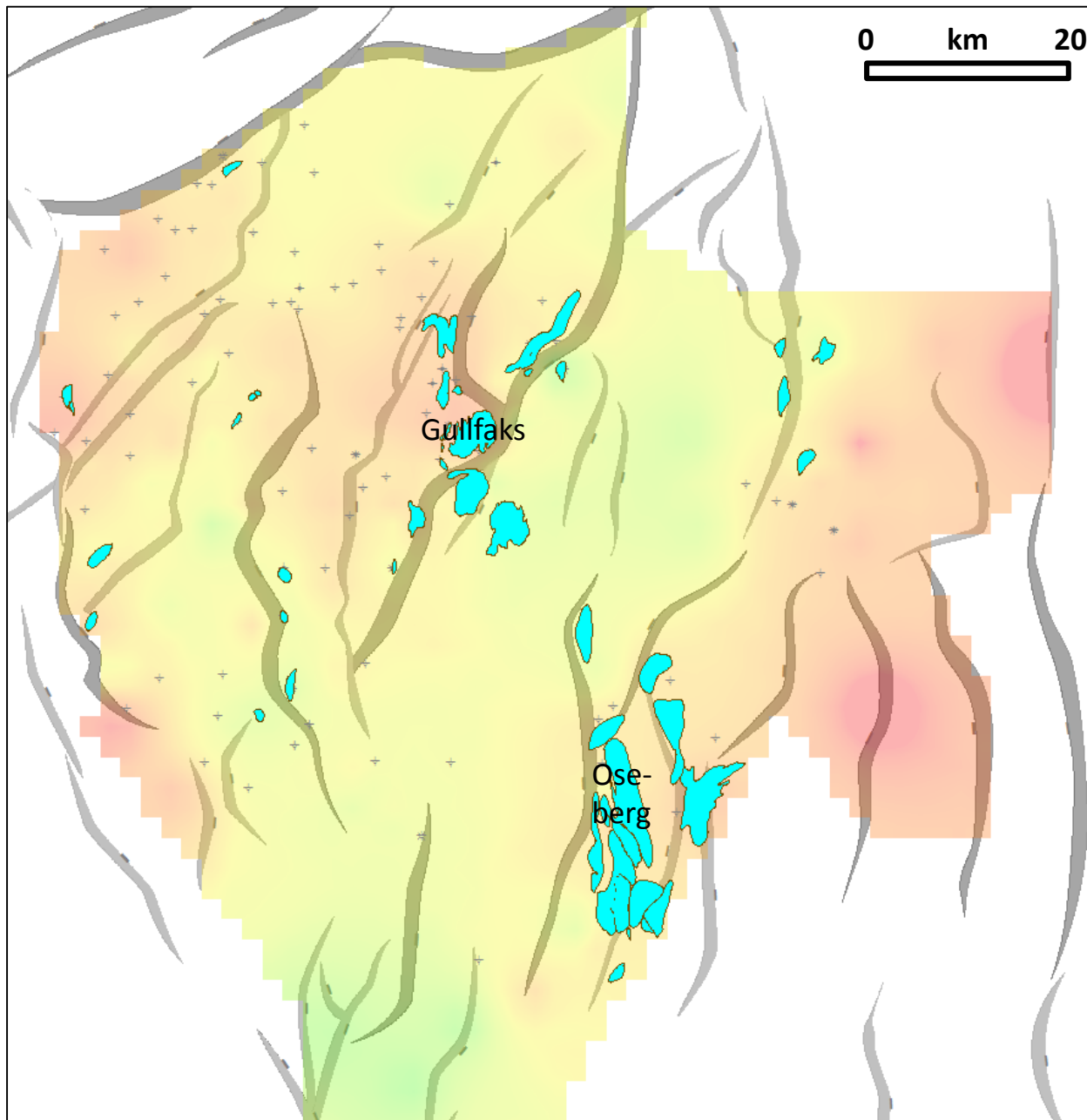
**Brent JU paralic sst
1971-2014**

114 discoveries
20 billion boe
av disc size 175 MMboe
293 expl wells
CoS 39%

**Brent JU paralic sst
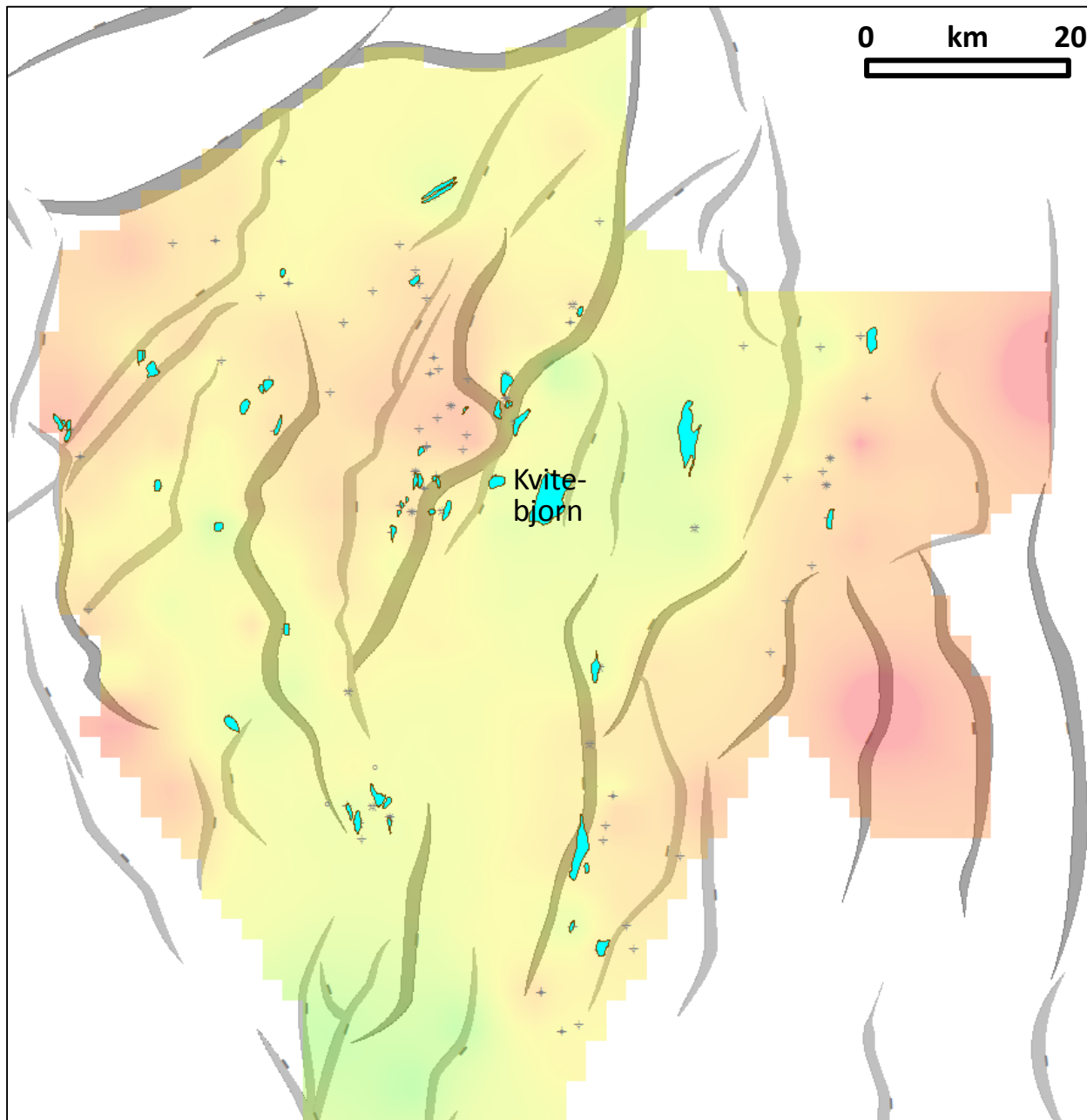Jul 1971-Jan 1978**

av disc size 271 MMboe

CoS 52%

**Brent JU paralic sst Feb 1978-Oct 1993**

av disc size 178 MMboe

CoS 28%

Gullfaks

Ose-berg

**Brent JU paralic sst
Nov 1993-Apr 2014**

av disc size 44 MMboe

CoS 45%

Kvite-bjorn

0        km        20

# Ways of identifying new potential
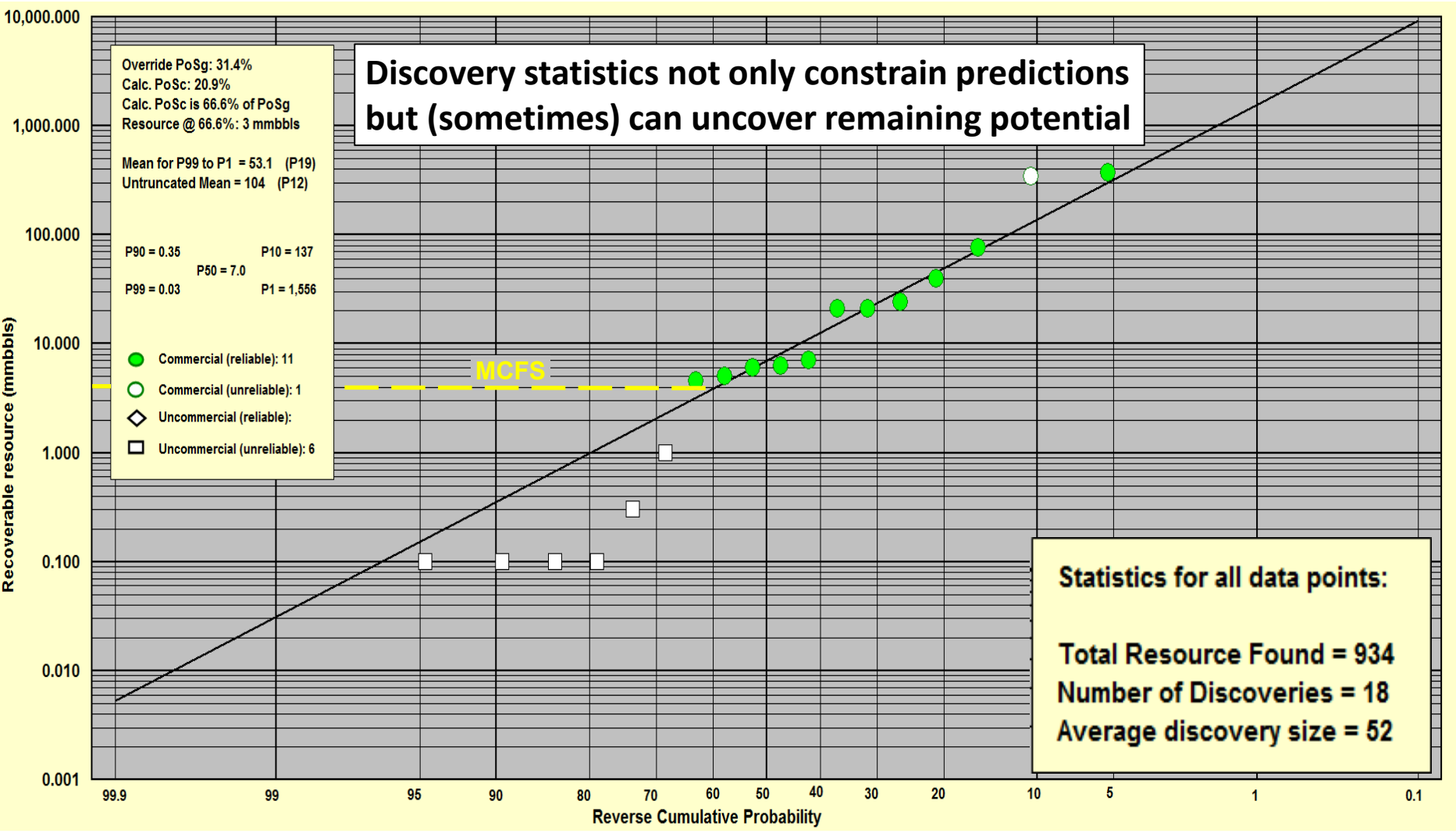
# Established plays have...

- Low risk

- Value to those with infrastructure

- Relatively small volumes yet to find

  Historical stats help decide value of continuing to explore where it already works
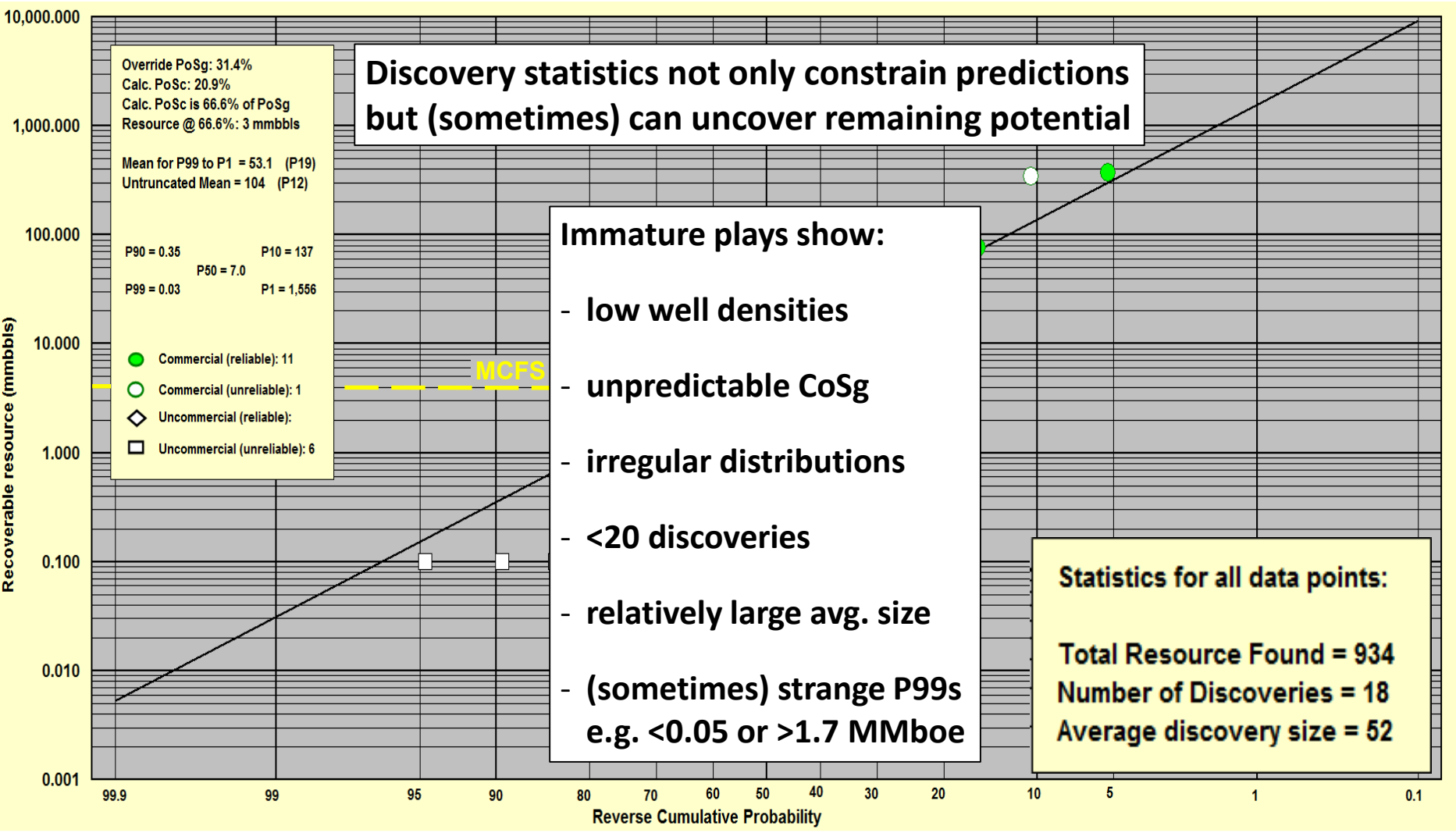
# So, before we spend money on seismic...

- Can we see when a play is over-mature?

- Or when a play is under-explored?

# What an underplayed play looks like (onshore Oman)



**20,000 km², 51 exploration wells, 31% CoS (67% commercial)**
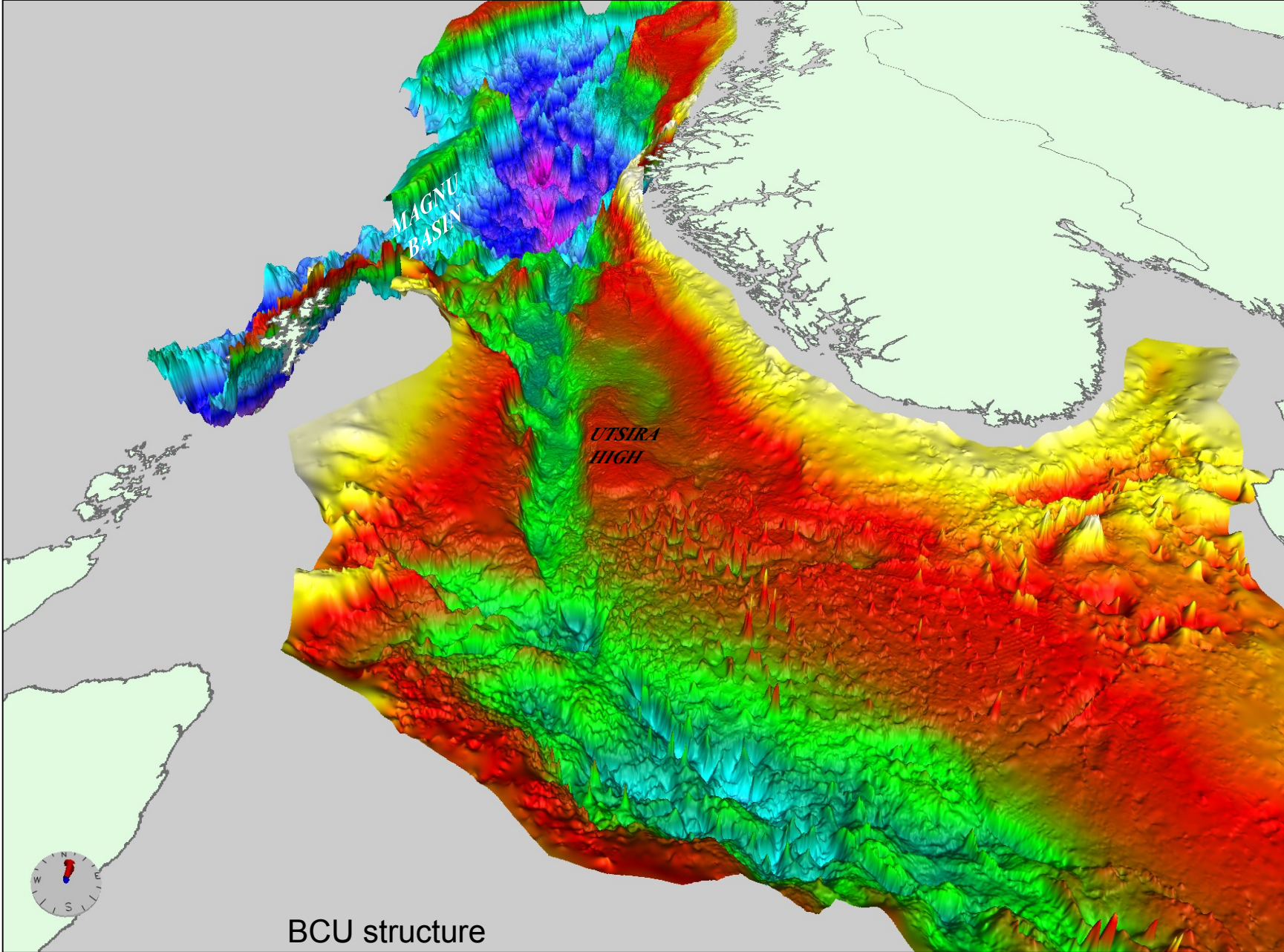
# What an underplayed play looks like (onshore Oman)



Override PoSg: 31.4%
Calc. PoSc: 20.9%
Calc. PoSc is 66.6% of PoSg
Resource @ 66.6%: 3 mmbbls

Mean for P99 to P1 = 53.1 (P19)
Untruncated Mean = 104 (P12)

P90 = 0.35        P10 = 137
        P50 = 7.0
P99 = 0.03        P1 = 1,556

● Commercial (reliable): 11
○ Commercial (unreliable): 1
◇ Uncommercial (reliable):
□ Uncommercial (unreliable): 6

**Discovery statistics not only constrain predictions but (sometimes) can uncover remaining potential**

MCFS

**Immature plays show:**

- **low well densities**
- **unpredictable CoSg**
- **irregular distributions**
- **<20 discoveries**
- **relatively large avg. size**
- **(sometimes) strange P99s e.g. <0.05 or >1.7 MMboe**

Statistics for all data points:

Total Resource Found = 934
Number of Discoveries = 18
Average discovery size = 52

Recoverable resource (mmbbls)

Reverse Cumulative Probability

**20,000 km² , 51 exploration wells, 31% CoS (67% commercial)**

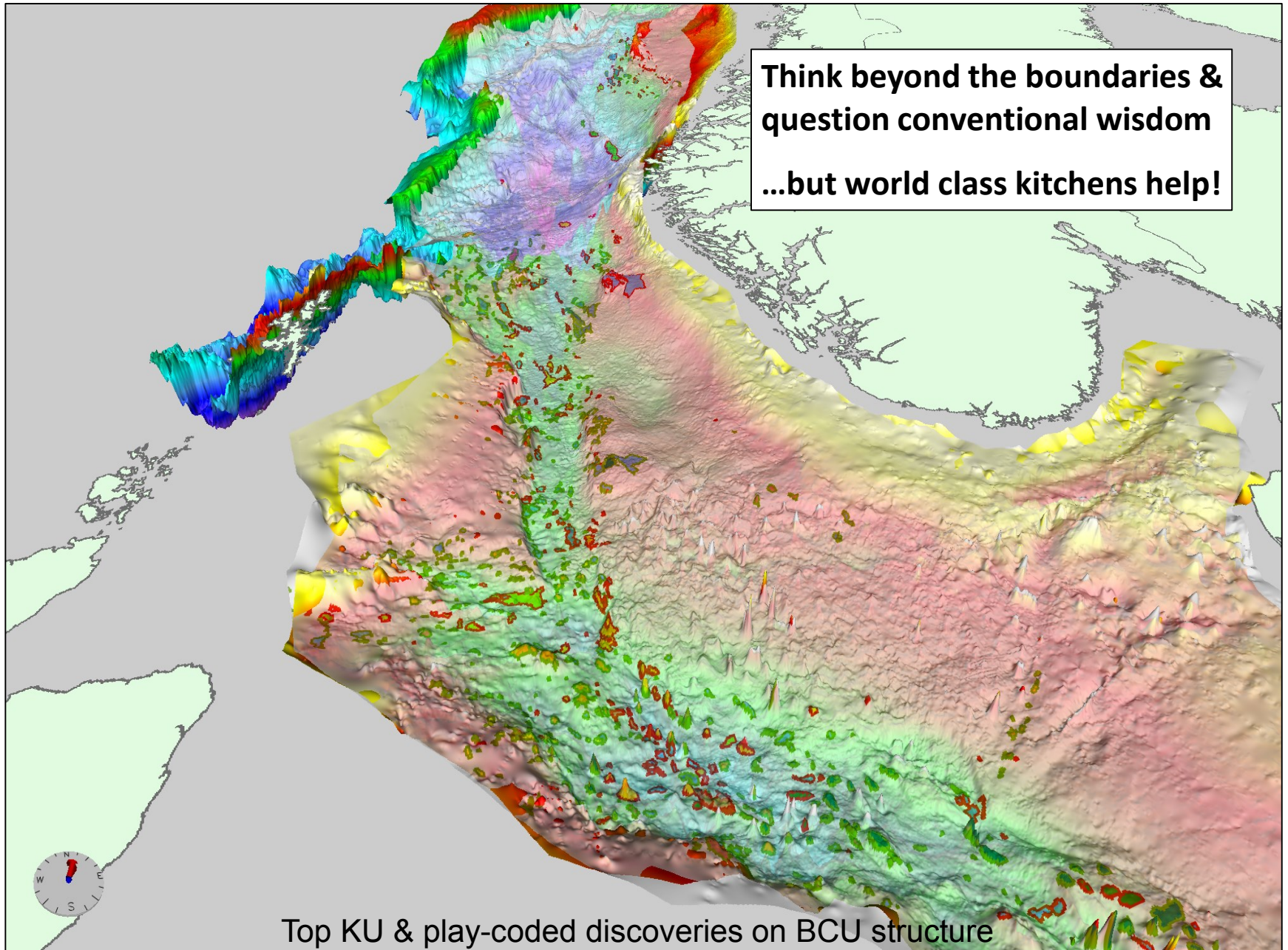**And why take the extra risk of exploring an unproven play?**

- Volumes & value…

- …if it works

# Why did it take so long to find Johan Sverdrup?



MAGNU BASIN

UTSIRA HIGH

BCU structure

# Why did it take so long to find Johan Sverdrup?



Think beyond the boundaries & question conventional wisdom

...but world class kitchens help!

Top KU & play-coded discoveries on BCU structure

# How do you identify new part plays where the risk is worth taking?

- Analogues

- Sediment thicks

- Indications of hydrocarbons

- Seismic

# In areas like Barents Sea, E Shetland Platform, NO-DK Basin

- Unless you have a large prospect / set of prospects…

- …it is probably not worth taking the extra risk that a new play will not work

    But a large closure or anomaly probably caught your attention in the first place!

# Where are the new part plays which are worth chasing?
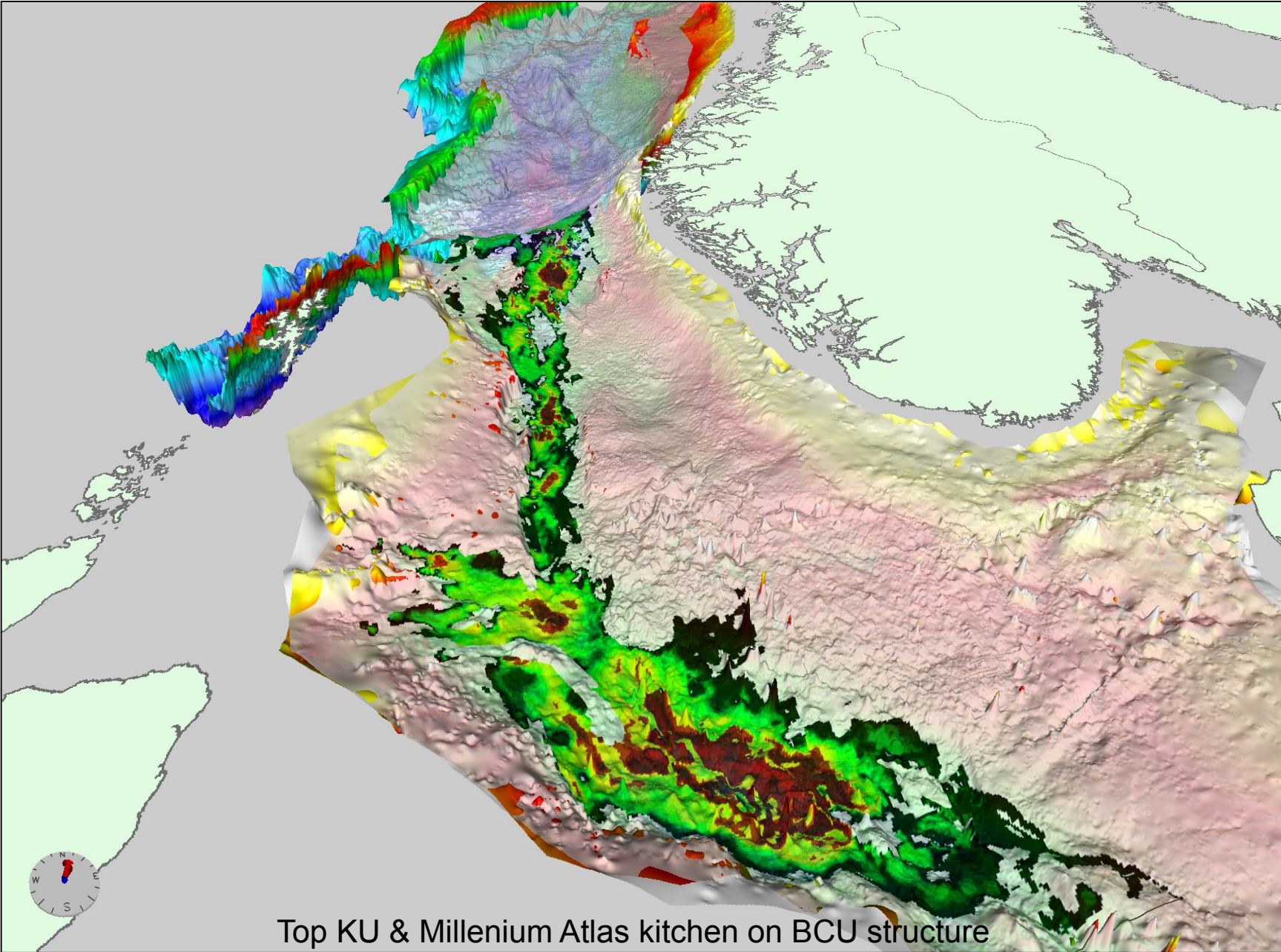


Top KU & Millenium Atlas kitchen on BCU structure

# Where are the new part plays which are worth chasing?

(without giving away my favourites in Norway, UK & Denmark!)

- On the margins of world class kitchens

- Highs, ridges & elbows where hydrocarbons will focus

- Above, around & below salt structures

- In proven basins where imaging is poor

- Deeper than prevailing models have advised

- Any under-explored half grabens with evidence for charge

# And strat traps are tough

- Charge focus is often challenged

- Both trap & well location live or die with pinch-out line... which is sub-seismic
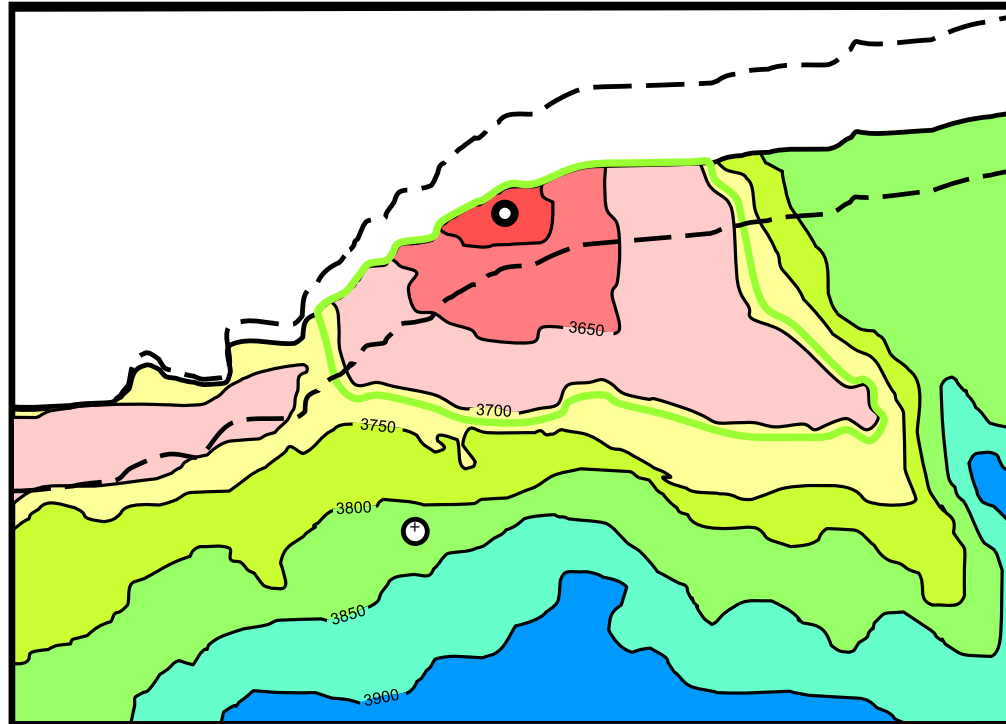


- Structurally consistent flat spots help...

- ...but an amplitude anomaly is nothing more than that without rock

- And without DHI, historical data shows there is rarely follow-on after first discovery

# Conclusions

# Conclusions

- The North Sea region is a world class hydrocarbon province

- There is significant room for undiscovered resources on margins of basin & deeper

- You should question boundaries & keep your play analyses evergreen

- To find significant volumes requires stepping outside your comfort zone

- Use "what if it works" mentality

- Historical statistics & seismic can justify your choice

- But significant risk will remain...
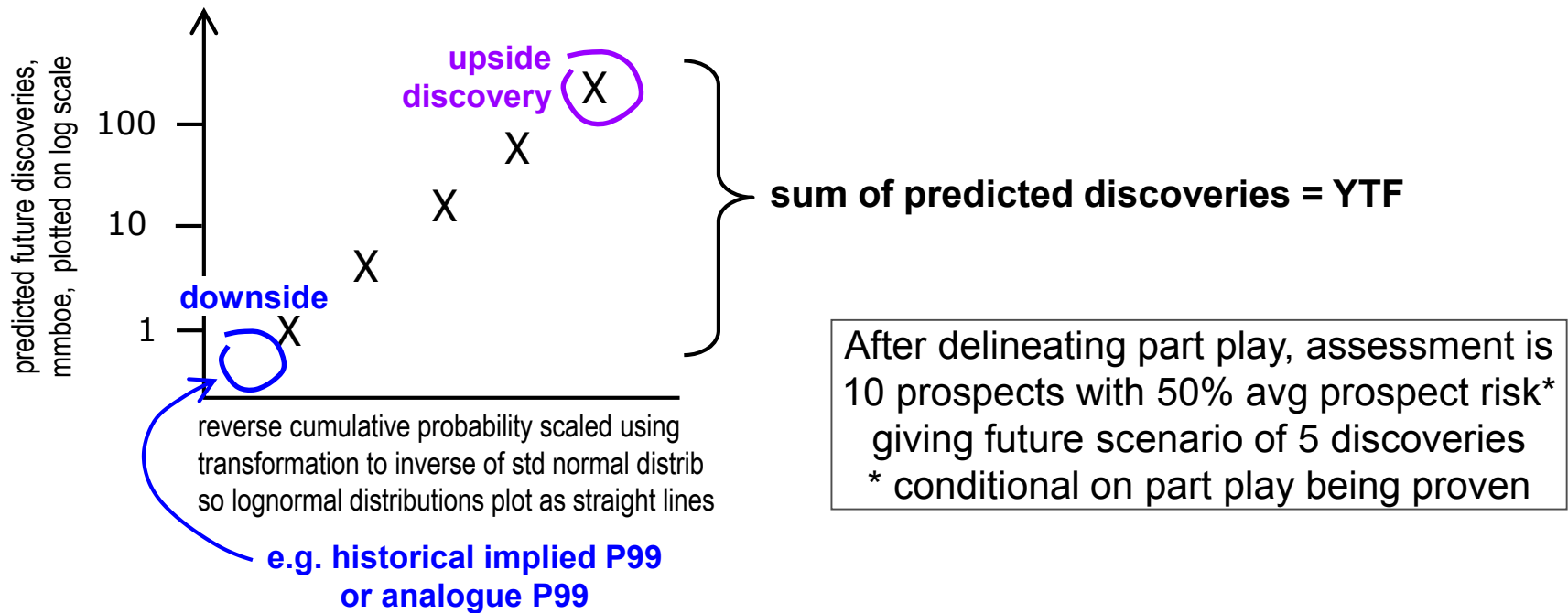
- ...& be realistic on size

# Predicting future discoveries

# What do historical statistics tell us about exploring plays?

- Size of largest future discovery + sweetspot area has largest effect on YTF (& economics)

- New plays & sweetspot extensions contain most volume & value (unless already player)

- YTF in unproven part plays is either 0 MMboe or, if it works, typically ≥200 MMboe

- CoSg is usually >50% after first discovery in sweetspot (except where imaging is poor)

- Not much YTF in strat traps… unless proven DHI

- Hard to predict what makes certain plays world class

# Predicting future discoveries in a part play – aka Yet-to-Find

- YTF is likely to be significantly wrong without seismic

  - but helps rank & decide on data

- Probabilistic YTF estimates tend to be overoptimistic

- Each play is unique

  - But historical data provide constraints to upside (e.g. MMboe/1000km$^2$)



predicted future discoveries, mmboe, plotted on log scale

**upside discovery**

**downside**

100

10

1

**sum of predicted discoveries = YTF**

reverse cumulative probability scaled using transformation to inverse of std normal distrib so lognormal distributions plot as straight lines

**e.g. historical implied P99 or analogue P99**

After delineating part play, assessment is 10 prospects with 50% avg prospect risk* giving future scenario of 5 discoveries
* conditional on part play being proven

**Theoretically all we need is:**

– area of play segment

– upside discovery size

– downside discovery size

– no. of discoveries (prospects x PoSg)
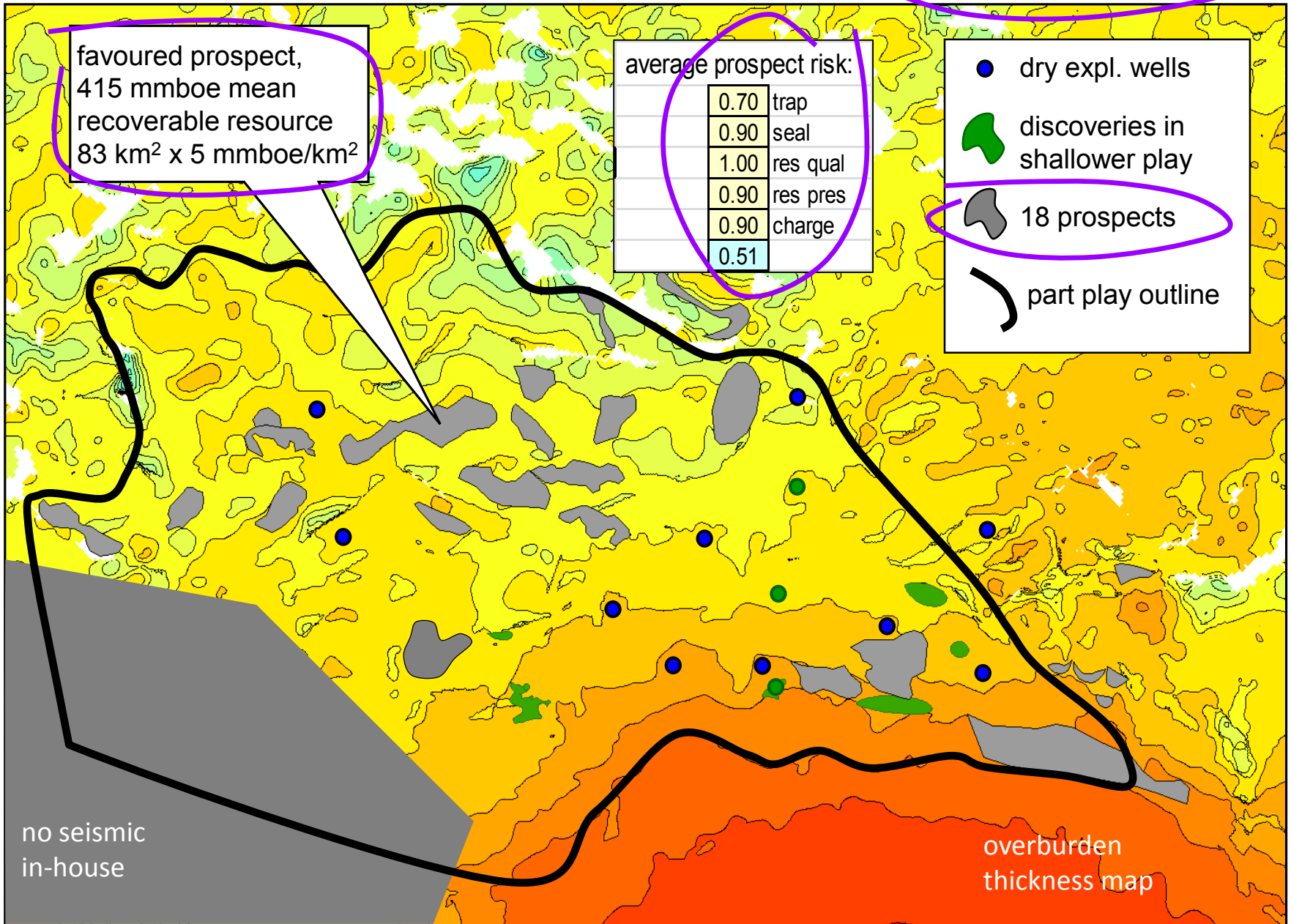
– chance of being proven

**But use different scenarios:**

– largest discovery may not be that large

– many discoveries are smaller than model

– area of future fairway is optimistic

– unproven part plays often fail…
  but, if it works…
  there are more discoveries than expected



e.g. closure area of anticipated prospect x P50 MMboe/sq km

sum of predicted discoveries = YTF
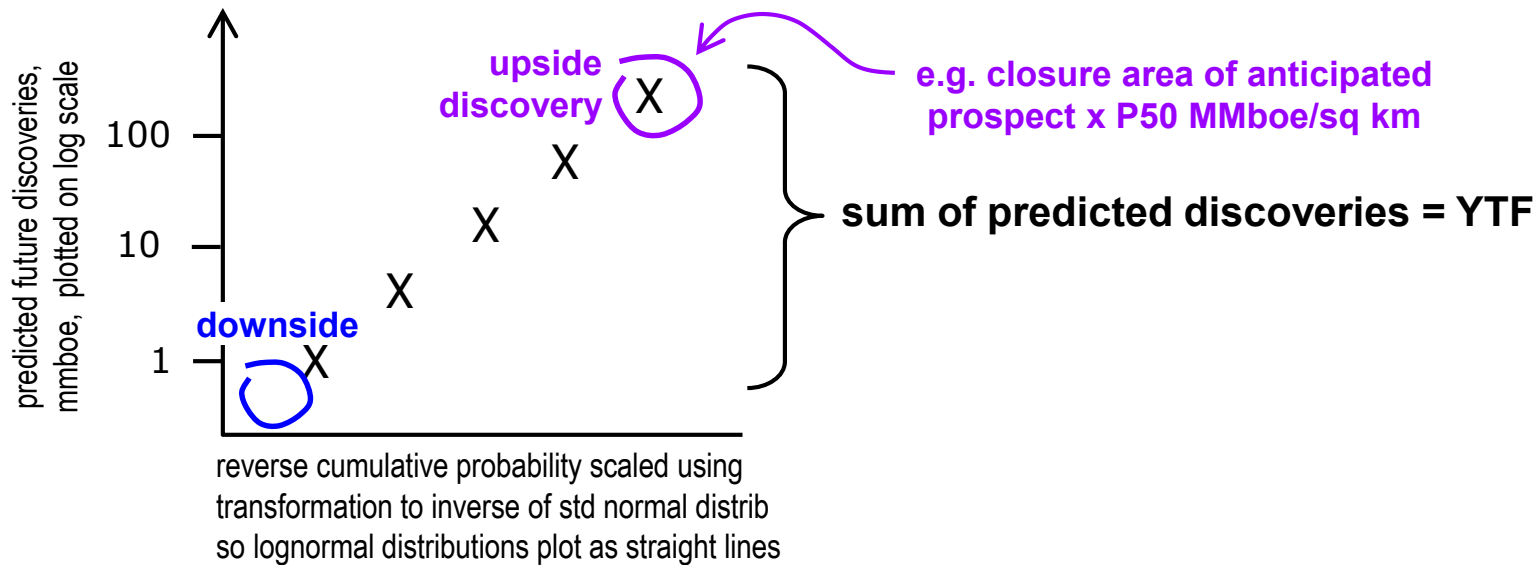
from Quirk et al. 2017. Yet-to-find in play analysis

# Example of scenario-based YTF calculation – part play outline

favoured prospect,
415 mmboe mean
recoverable resource
83 km² x 5 mmboe/km²

average prospect risk:

| | |
|---|---|
| 0.70 | trap |
| 0.90 | seal |
| 1.00 | res qual |
| 0.90 | res pres |
| 0.90 | charge |
| 0.51 | |

- ● dry expl. wells
- ● discoveries in shallower play
- ● 18 prospects
- part play outline

no seismic
in-house

overburden
thickness map

# Mid case YTF scenario plotted as future discovery size distribution



Mid case future discovery scenario

Override PoSg: 58.0%
Calc. PoSc: 32.2%
Calc. PoSc is 55.5% of PoSg
Resource @ 55.5%: 32 mmboe's

Mean for P99 to P1 = 149   (P24)
Untruncated Mean = 210   (P18)

P90 = 4.0          P10 = 415
           P50 = 40.7
P99 = 0.60          P1 = 2,757

O  Commercial (reliable): 5

◇  Uncommercial (reliable): 4

MEFS

upside discovery

assumed P99

check average size is less than historical

Statistics for all data points:

Total Resource Found = 866
Number of Discoveries = 9
Average discovery size = 96

Recoverable resource (mmboe's)

Reverse Cumulative Probability

from Quirk et al. 2017. Yet-to-find in play analysis. Journal of Petroleum Geology, 40, 217-48
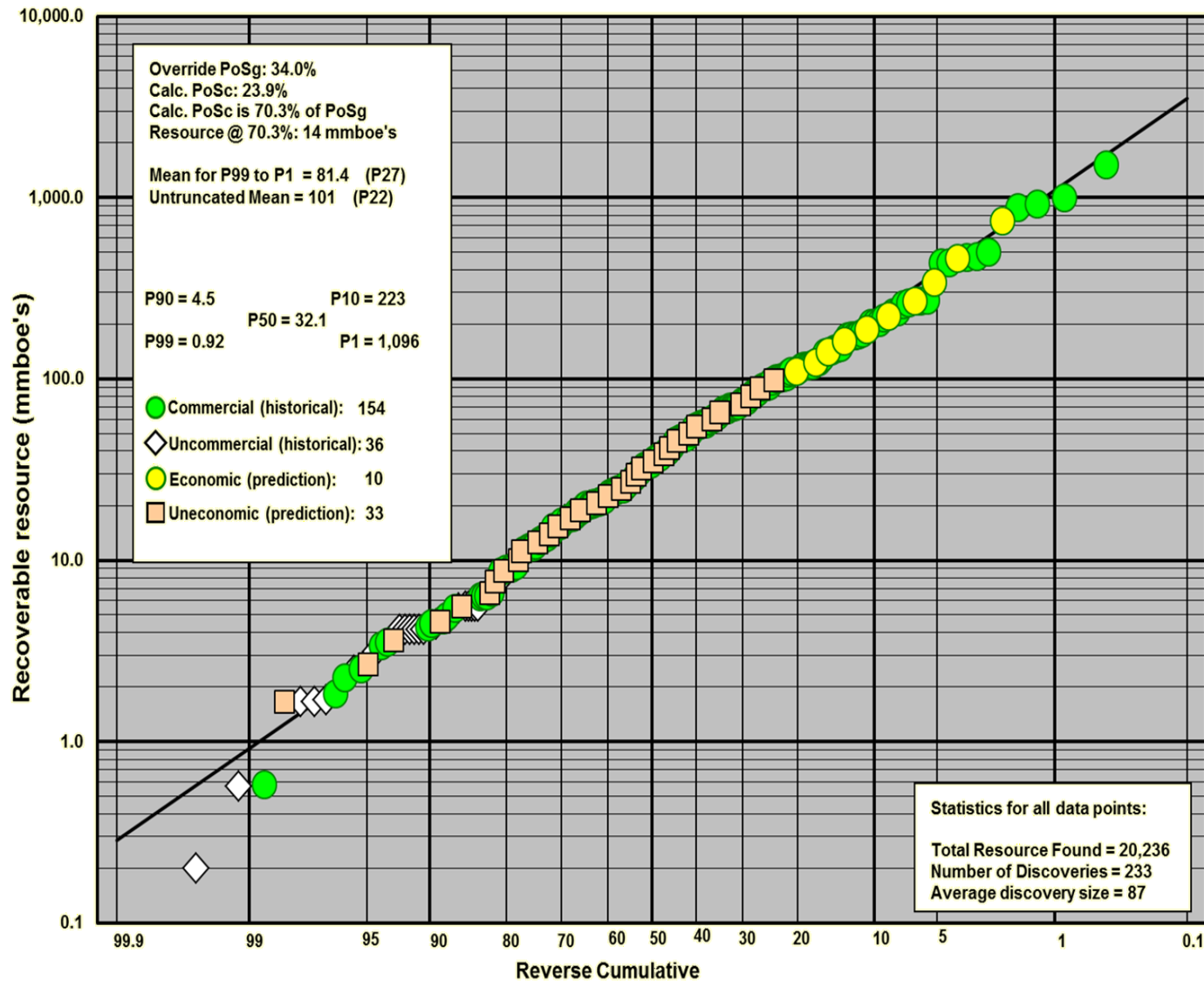
# Low case, mid case & high case YTF scenarios
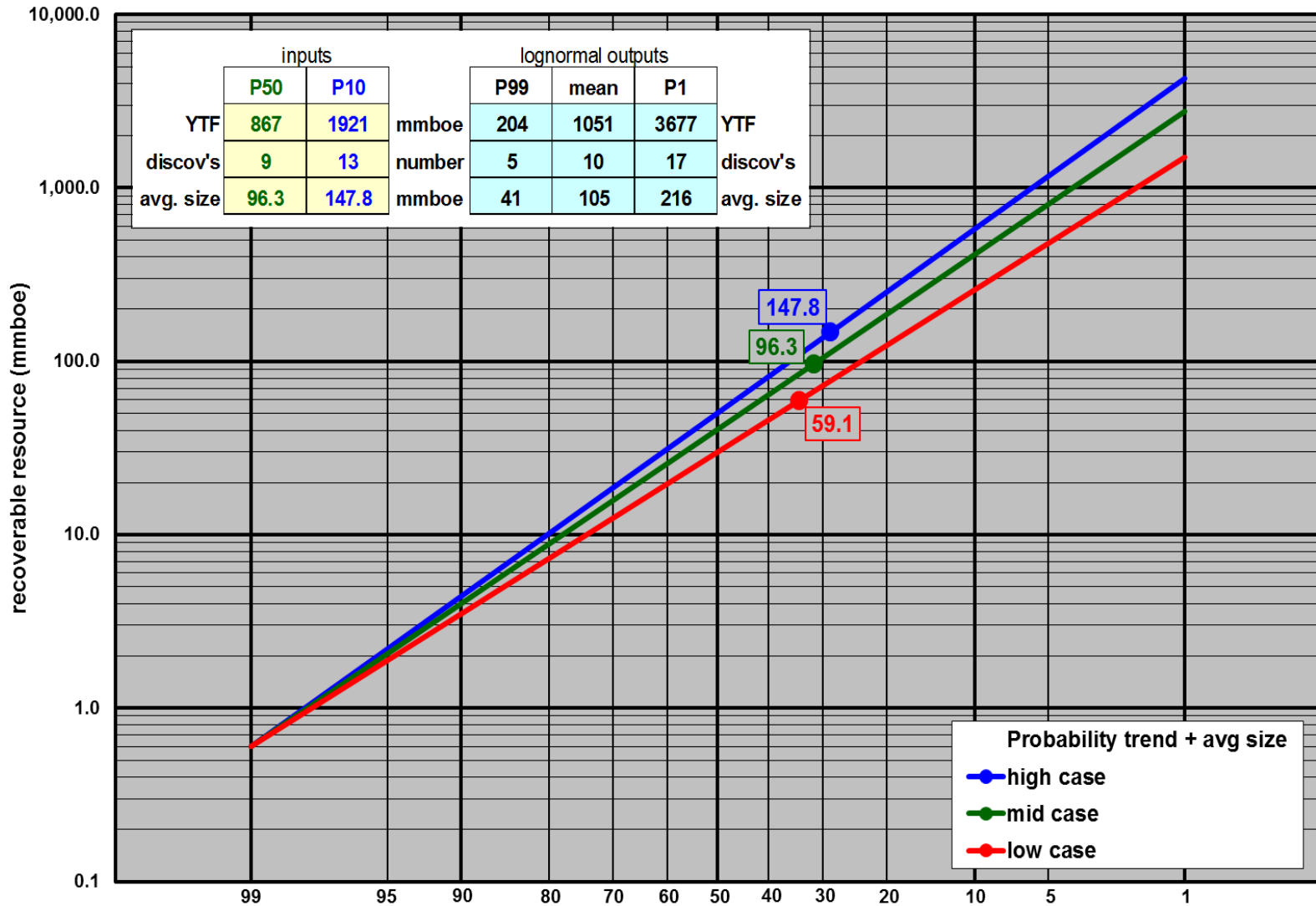
# URR scenario for a proven part play, deepwater GoM
Already Found (historical) + YTF (prediction) as combined distribution



from Quirk et al. 2017. Yet-to-find in play analysis. Journal of Petroleum Geology, 40, 217-48

# Historical data provide the following important data

## In proven part plays

- Average discovery size (future will be smaller)

- Size distributions for small future discovery size (e.g. implied P99 resource & P90 area)

- MMboe/km$^2$ for discoveries (e.g. closure area x P50 MMboe/km$^2$ for size of large lead)

- Past discovery rate ≈ future CoSg

- Chance of finding reservoir, seal & charge remains similar once play established


## In unproven part plays

- MMboe/1000km$^2$ for analogue play

- Features/1000km$^2$ for analogue structural domain

- 50-67% of offshore discoveries get developed (cf. >95% of onshore discoveries)


**Use group wisdom to estimate chance that play works**