

# Randomness, Serendipity and Luck in Petroleum Exploration

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**COLORADO SCHOOL OF MINES**  
EARTH • ENERGY • ENVIRONMENT

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# Talk outline

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- What people say about luck in exploration.
- What data and randomness models suggest.
- Implications for you.

# Random (?) ramblings by management

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***“I do not need a good geologist;  
I need a lucky one.”***

Anonymous CEO

***“Lucky beats clever, every time.”***

A New Ventures Manager

# DeGolyer made me more curious

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## Everette Lee DeGolyer

AAPG Sidney Powers Memorial  
Award in 1950

Called "petroleum industry's #1  
geologist" after his death in 1956

Geophysical Research Corporation

DeGolyer and MacNaughton

Core Laboratories



*"It takes luck to discover oil.  
Prospecting is like gin rummy.  
Luck enough will win but not  
skill alone.*

*Best of all are luck and skill in  
proper proportion, but don't  
ask what the proportion  
should be. In case of doubt,  
weight mine with luck."*

# Survey on luck in petroleum exploration

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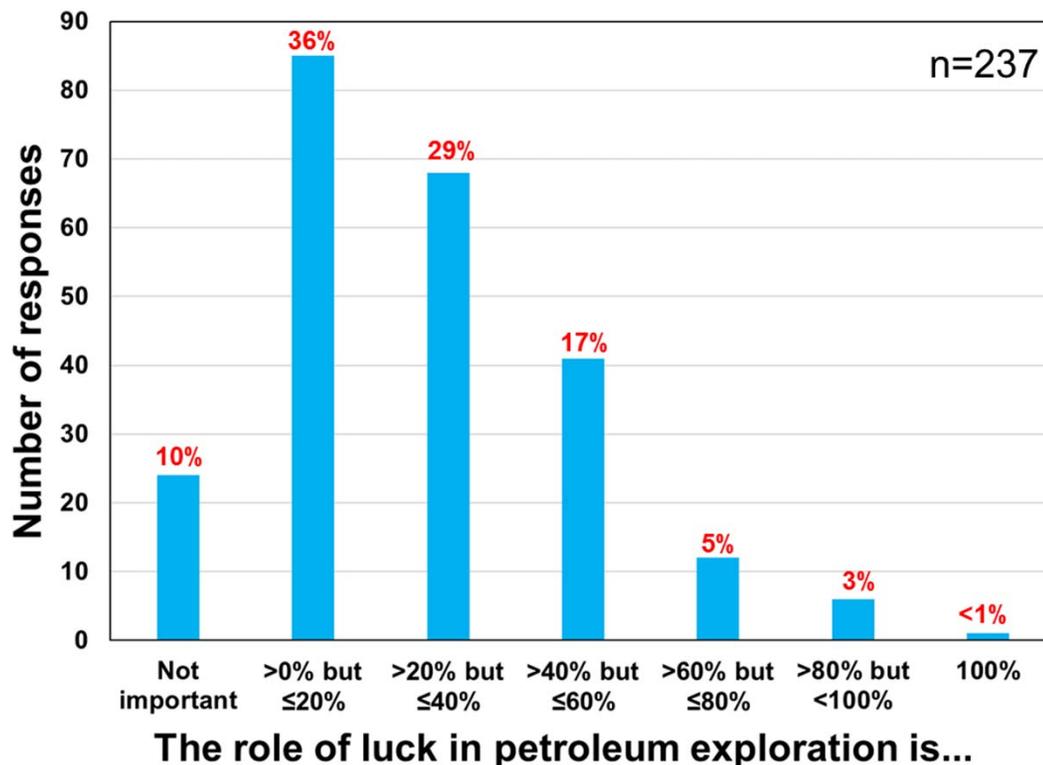
*“Some think that outcomes of petroleum exploration depend on luck and technical skill. In your opinion, **what is the role of luck in the outcome of petroleum exploration programs?**”*

- Background information collected:
  - ▣ Highest educational degree,
  - ▣ Type of company,
  - ▣ Years of experience,
  - ▣ Highest level position in exploration projects.



# Perception of luck in exploration by industry practitioners

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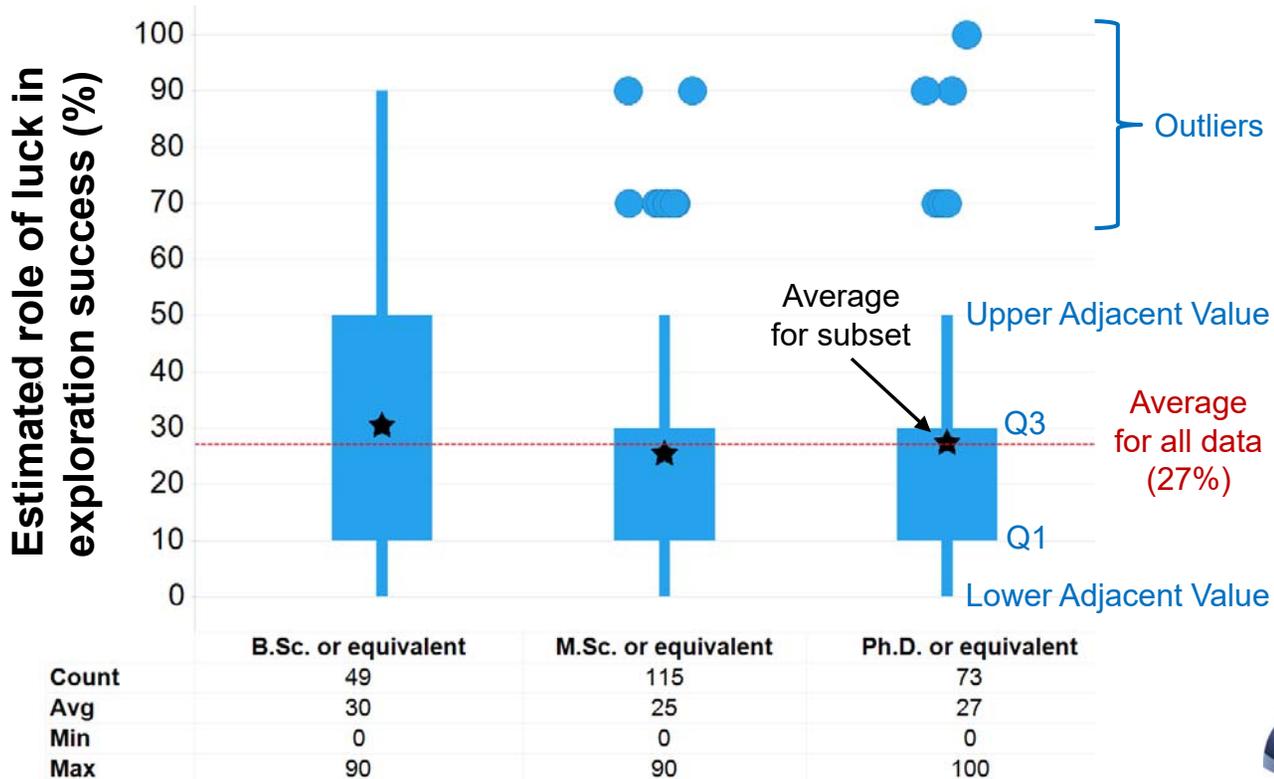


- 90% of respondents think that luck plays some role in the outcomes of petroleum exploration.
- On average, respondents think that the role of luck is 27% (median 30%).

Milkov and Navidi (2019, AAPG Bull.)

# Highest academic degree

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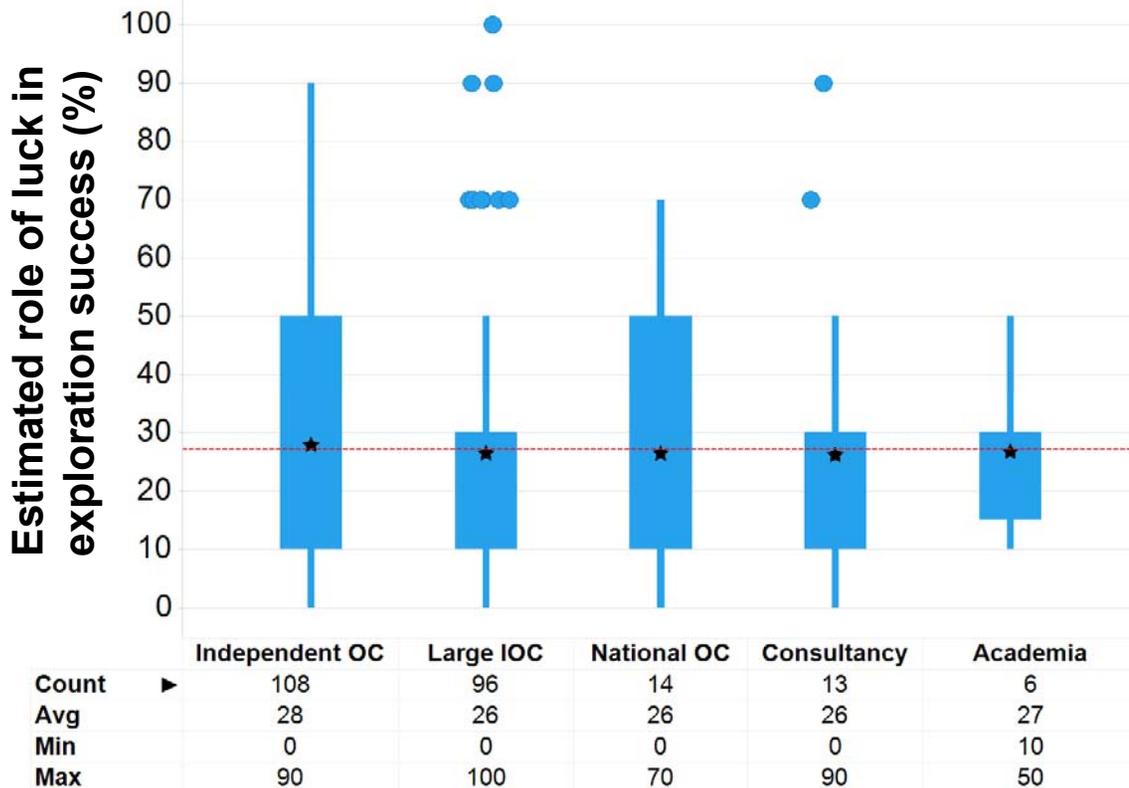


- Education has little influence on the perception of the role of luck.

Milkov and Navidi (2019)

# Company type

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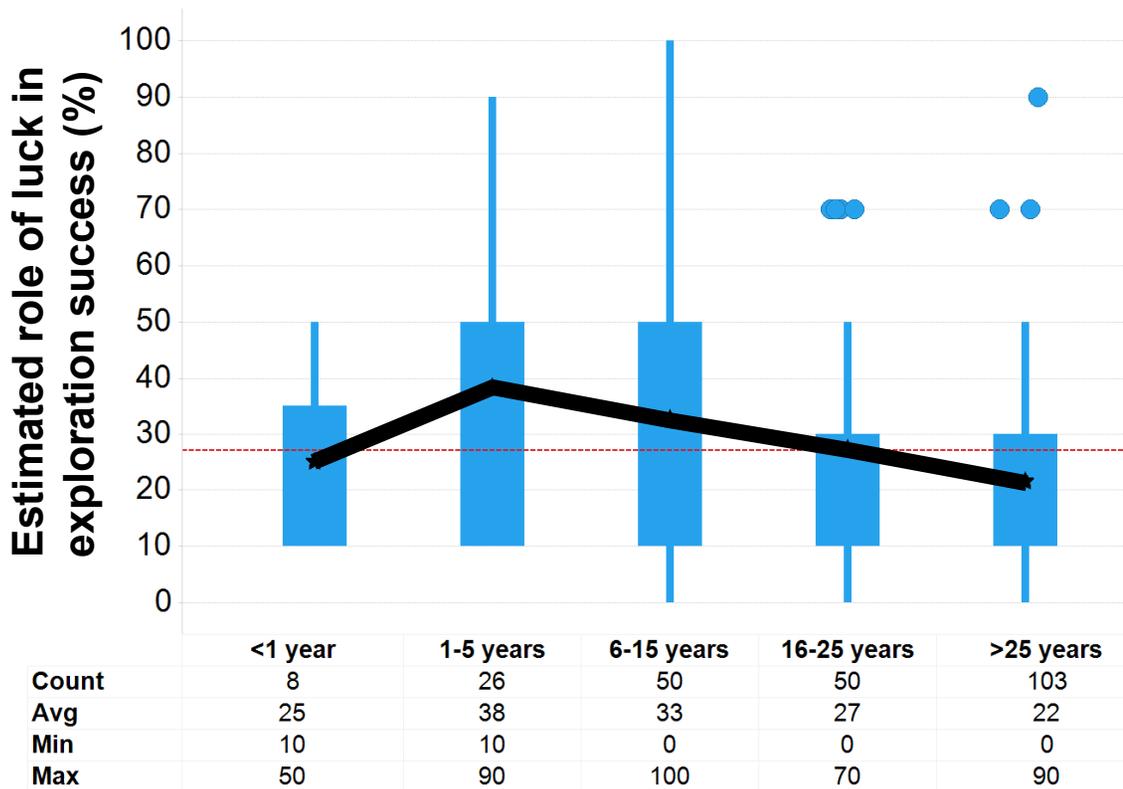


- The type of company has little influence on the perception of the role of luck.

Milkov and Navidi (2019)

# Years of experience

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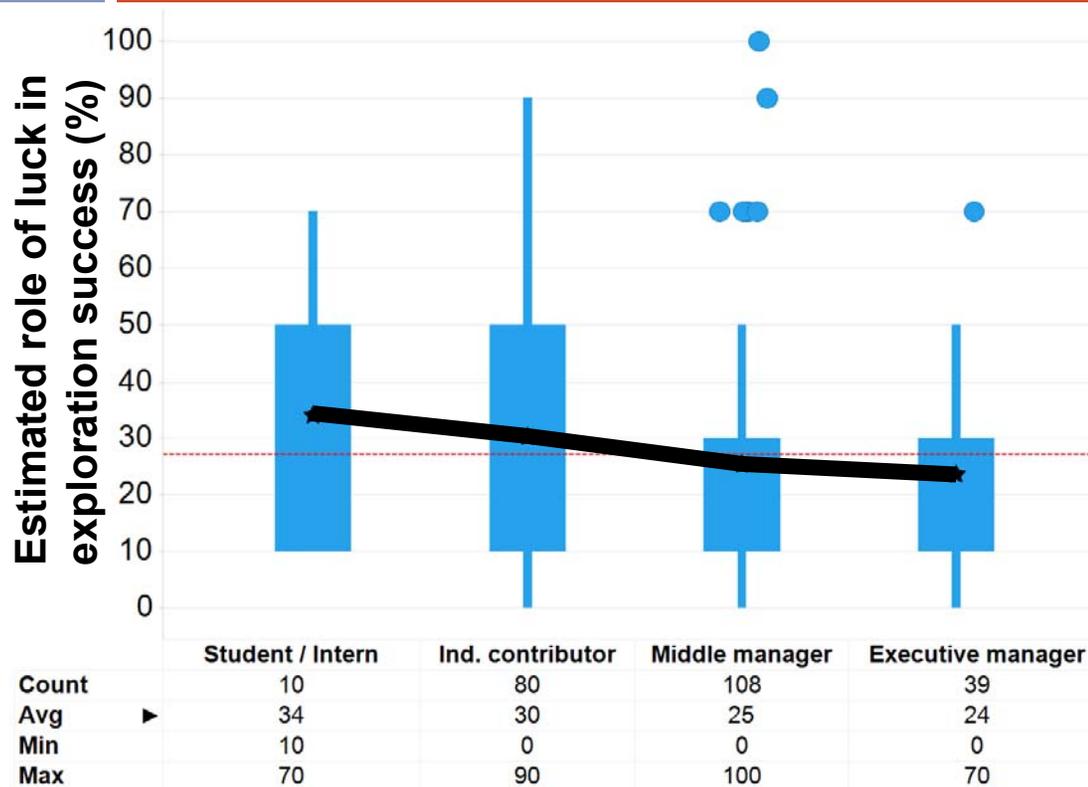


- Explorers with more years of experience assign lower significance to the role of luck in exploration.

Milkov and Navidi (2019)

# Highest-level position in exploration projects

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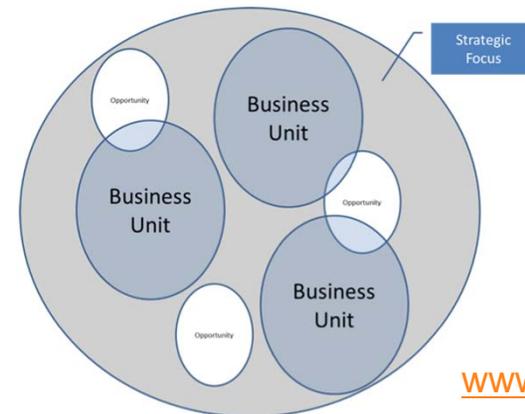
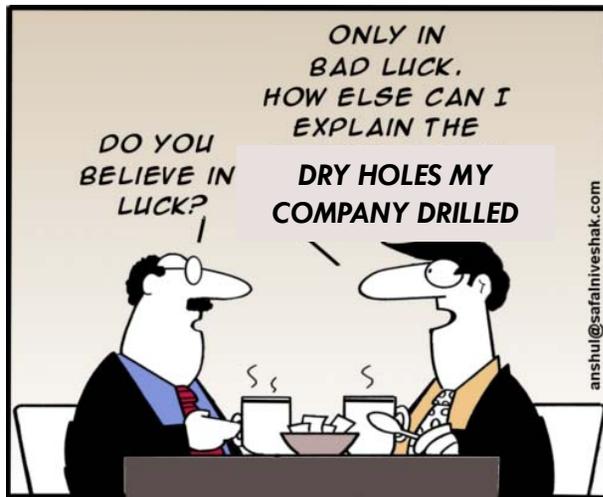
- Explorers with higher positions and larger responsibilities assign lower significance to the role of luck in exploration.

Milkov and Navidi (2019)

# Why more experience and higher position reduce appreciation of luck factor?

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- Self-serving attribution and overconfidence biases?
  - ▣ Believe that their contribution to success is more valuable than it actually is.



[www.emba.mit.edu](http://www.emba.mit.edu)

- Appreciation of portfolio approach?
  - ▣ Executive managers of Large IOCs and NOCs average 16% (n=10) while overall executive group averages 24% (n=39).

# The concept of luck

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“Luck is success or failure apparently brought by chance rather than through one's own actions.”

“Small probability events in essentially random processes” (Rescher, 1995).

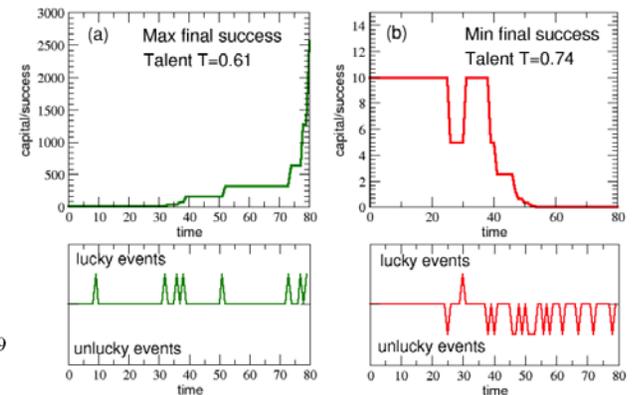
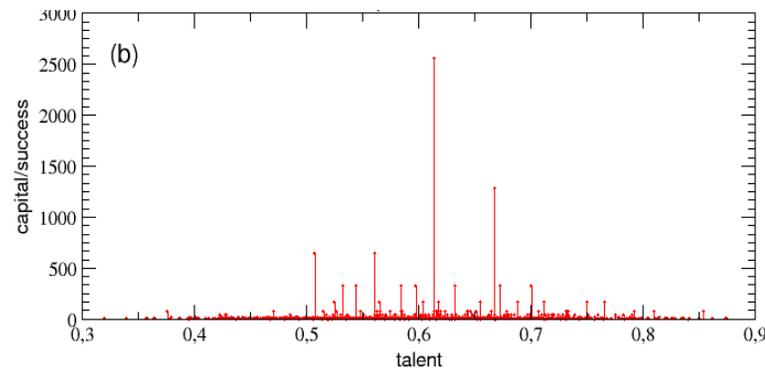
Good luck



Bad luck

# Role of luck in life – mathematical model

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- 1000 people, each starts with the same capital.
- Normal distribution of talent.
- Random walks. Lucky events (green circles) double the capital, unlucky (red circles) events halve the capital.

- The most successful individuals are not the most talented ones.

- Strong correlation between success and luck.

Pluchino et al. (2018)

# Real life example

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[https://www.reddit.com/r/funny/comments/7gp3ye/this\\_vanity\\_tag/](https://www.reddit.com/r/funny/comments/7gp3ye/this_vanity_tag/)

# Was Jeff Bezos lucky?

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1999

<http://www.whiskeyriff.com/2018/01/02/amazon-founder-jeff-bezos-in-his-office-in-1999-is-all-the-motivation-you-need-for-2018/>



2018

<https://twitter.com/jeffbezos>

~130 billion \$



*"The price of admission to space is very high. I'm in the process of converting **my Amazon lottery winnings** into a much lower price of admission so we can go explore the solar system."*

Based on Koetsier (2018)

# Mark Zuckerberg knows he was lucky

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“You don't get to be successful like this just by being hard working or having a good idea... You have to get lucky in today's society in order for that to happen.”



Photo by Bloomberg. Facebook could encompass one-third of the world's population by this time next year, according to New York magazine.

Mark Zuckerberg is 33 years old, worth almost \$70 billion, according to Forbes, and is running one of the largest, most influential tech companies in the world.

Why and how is he so successful? Luck has a lot to do with it, he says.

<https://finance.yahoo.com/news/mark-zuckerberg-success-mine-only-190652552.html>

# Definitions

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- **Randomness** is the lack of predictability in events.
- Chance is a possibility of something happening in an essentially random process.
- **Luck** describes good or bad chance events with low probabilities that actually happened.
- **Serendipity** is finding valuable things that were not sought.

# Examples of serendipitous petroleum discoveries

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## Countries and Basins

- Germany - first oil discovered in 1858 at Wietze in the Lower Saxony Basin by the well drilled to locate coal.
- Canada, Australia, Argentina, Volga-Urals (Russia)...
- Many discoveries in the first half of 20<sup>th</sup> century.

## Plays

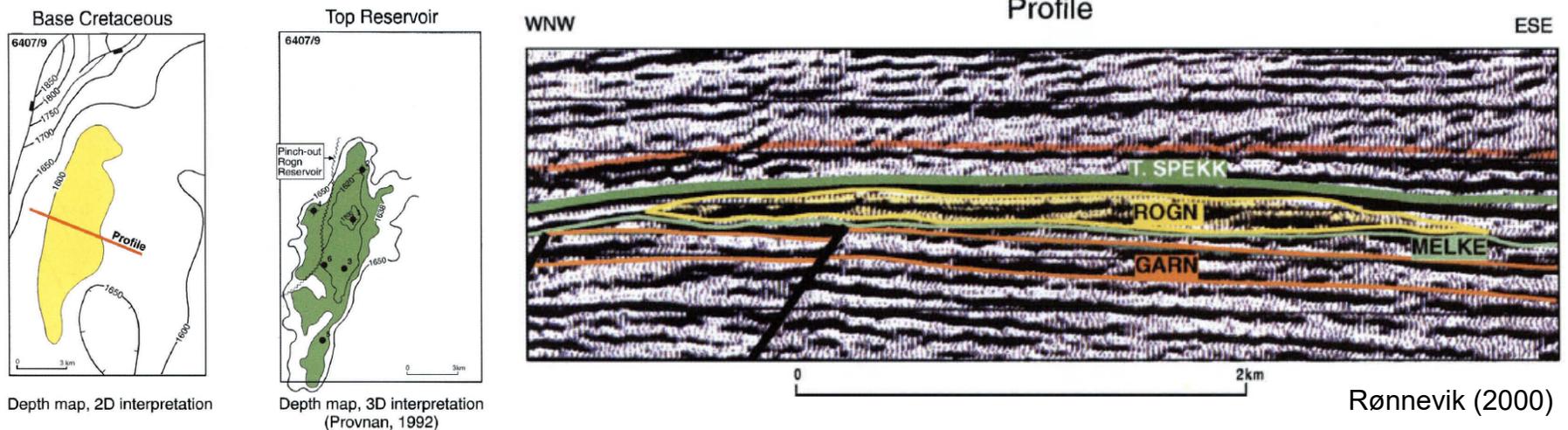
- Basement play, West of Shetlands, UK.
- Fat Sand play (Triassic Solling Formation), Northern Dutch offshore.
- Barnett oil play, USA.
- .....

## Fields

- Groningen gas field (Netherland) - 100 tcf.
- Dayung gas field (Indonesia) - 15 tcf.
- Alba oil field (UK North Sea) - produced >425 mmbo.
- Draugen field (offshore Norway)
- ...

# Example of serendipity in conventional petroleum exploration

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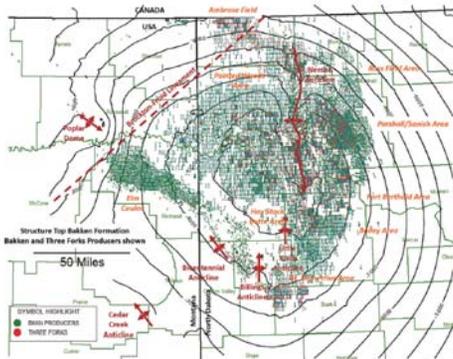


- The first well on Draugen (offshore Norway) targeted a low-relief Middle Jurassic structure with reservoir in the Garn Formation.
- Major surprise - the discovery was made in the Rogn Formation (Upper Jurassic), by then yet unknown reservoir.

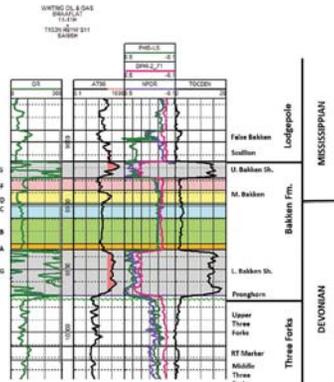
# Example of serendipity in unconventional petroleum exploration

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Structure map on top Bakken, CI=500 ft (Sonnenberg et al., 2017)

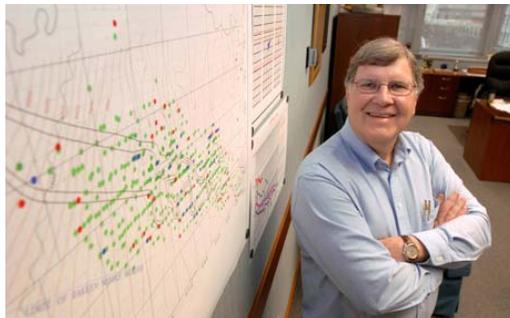


Well log display of Bakken (Sonnenberg et al., 2017)



- Elm Coulee Field, Montana – initial discovery (1996) of modern Bakken oil play in the Williston basin.
- Story told by Richard “Dick” Findley credited with discovery:
  - Drilled vertical well for bypassed oil on a small structural closure. **Were not targeting Bakken.**
  - On the way down to the target, **noticed 400-unit gas increase in Middle Bakken.** Thought “this is interesting”.
  - The original target (deeper) was non-commercial. **Decided to complete the Middle Bakken as a “bailout”.**
  - After a frac, had 157 BOPD initial potential. No steep decline, which was a surprise. Very different from Upper Bakken.
  - Called “Sleeping Giant Prospect”. Drilled first horizontal well in 2000, fracked, got over 400 BOPD. This became Elm Coulee.

<https://www.geoexplor.com/articles/2010/02/sourcing-an-oil-boom>



Sternbach et al. (2017)

# We do not know how common serendipitous discoveries are, but...

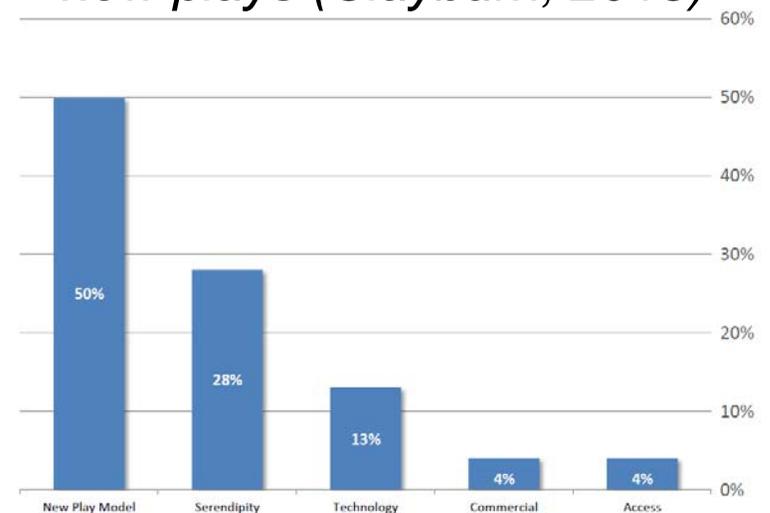
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*Perhaps >50% of conventional discoveries in the Permian basin are serendipitous (Elam, 1984)*

*74% of ~200 successful wells drilled in 2004-2006 were ... due to mere chance since relevant pre-drill predictions and evaluations ... were greatly different or wrong compared with the final results of drilled wells. But, all the above was sold and rewarded as geological “excellence”!*

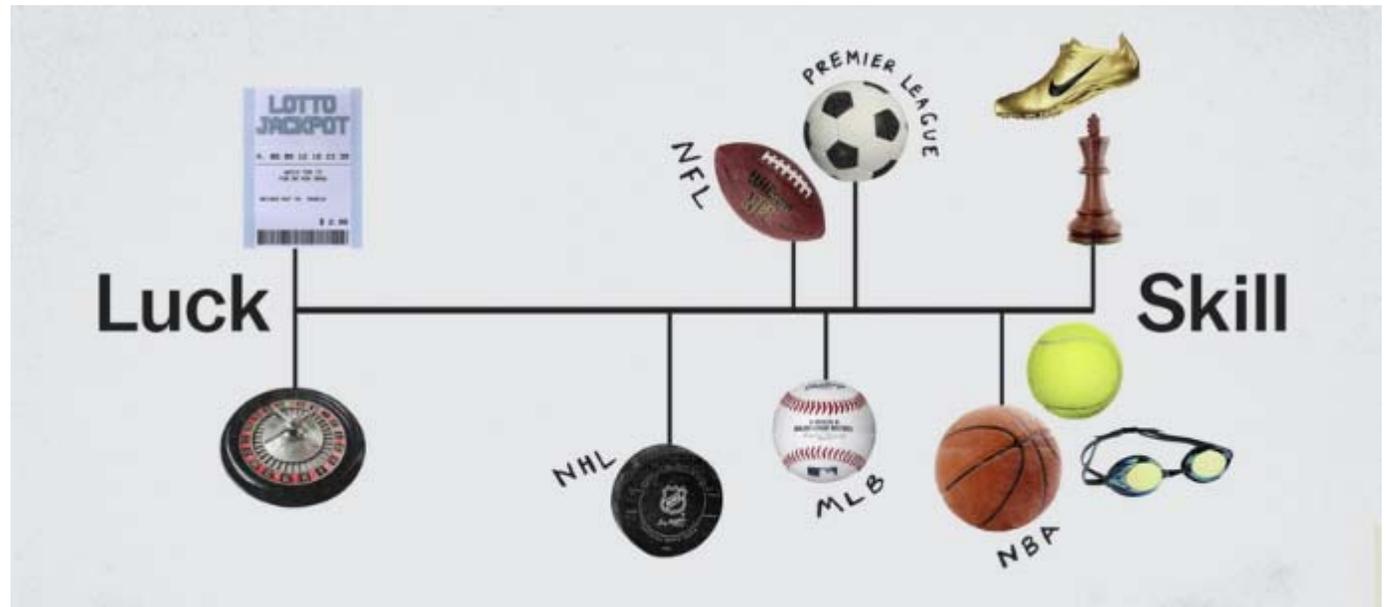
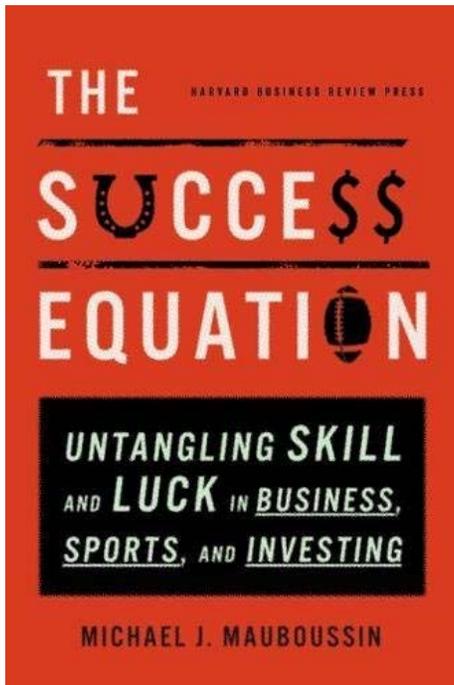
*(Albino Quadrelli, AGIP)*

*Critical success factors for new plays (Clayburn, 2018)*



# Luck-skill continuum in competitive activities

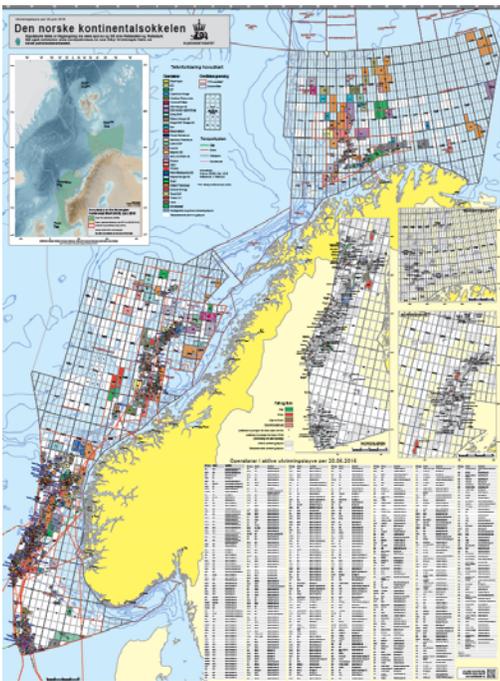
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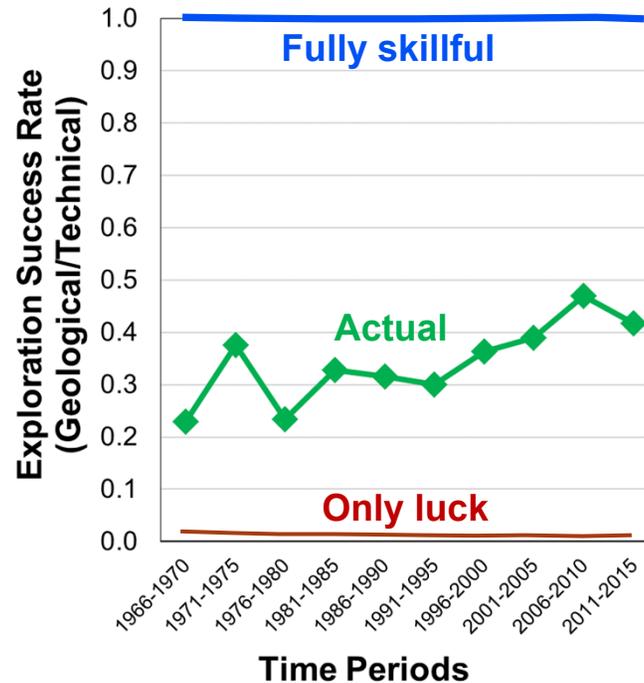
<https://www.vox.com/videos/2017/6/5/15740632/luck-skill-sports>

# Exploration success rates on the Norwegian Continental Shelf (NCS)

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<http://www.npd.no/en/Maps/Map-of-the-NCS/>

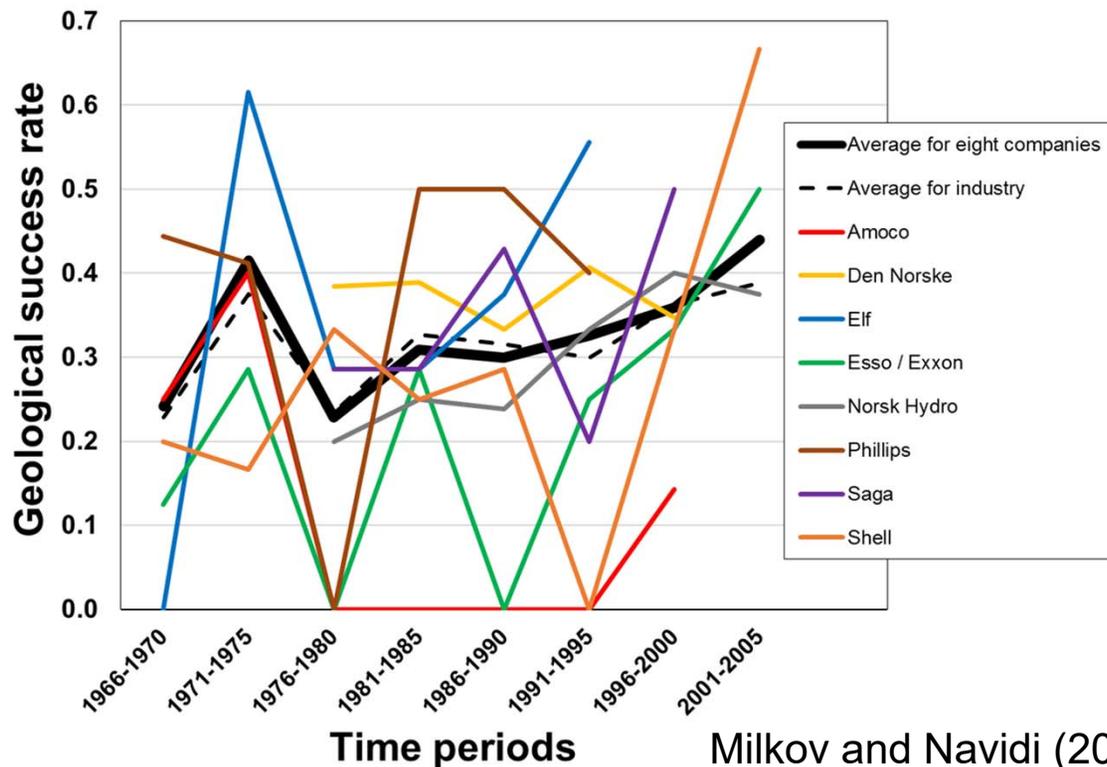


Milkov and Navidi (2019)

- Random drilling success rate 1.3% (mid-2017).
- 100% success if fully skillful.
- Industry average success rate increased from ~20% to ~40-50% over 50 years.

# Evidence of luck in exploration on the NCS

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- 8 largest companies drilled 497 exploration wells (of 636 total by the industry) in 1966-2005.
- Regression to the mean is a signal of luck.
- Consistency is a signal of skill.

# Measure of variance in success rate

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Number of wells drilled  
by each company      Success rate  
for each company      Overall  
success rate

$$z_i = \frac{\sqrt{n_i}(p_i - \bar{p})}{\sqrt{\bar{p}(1 - \bar{p})}}$$

Difference between  $i$ th company  
success and overall success, in  
units of standard deviation

- Used  $z_i^2$  to measure the difference between the success rate of company  $i$  and the overall success rate of the group ( $\bar{p}$ ).

# Actual vs simulated random results of exploration drilling

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	66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	Total
Shell	0.05	1.53	0.19	0.13	0.01	1.94	0.02	0.63	4.48
Amoco	0.00	0.01	1.18	1.34	1.29	1.94	1.43	-	7.18
Den norske	-	-	1.81	1.07	0.11	0.81	0.01	-	3.81
Elf	0.95	2.15	0.13	0.02	0.21	2.16	-	-	5.62
Esso/Exxon	0.59	0.48	0.30	0.02	1.71	0.11	0.01	0.09	3.30
Norsk Hydro	-	-	0.07	0.33	0.38	0.01	0.11	0.27	1.17
Phillips	2.03	0.00	2.07	0.34	0.38	0.12	-	-	4.94
Saga	-	-	0.13	0.04	1.10	1.09	0.86	-	3.21
Total	3.62	4.17	5.88	3.29	5.20	8.16	2.43	0.99	

- Values of  $z^2$  for each company for each 5-year period.

## Results for one simulation

- Generated 10,000 data sets in which variation was entirely due to chance (randomness).
- Computed values of  $z^2$  for each data set.

	66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	Total
Shell	0.69	0.17	3.28	1.36	0.01	0.11	0.52	0.14	7.28
Amoco	1.27	0.30	1.18	0.01	0.02	0.55	1.37	-	4.70
Den norske	-	-	1.81	0.17	0.66	0.01	0.3	-	2.95
Elf	0.14	0.05	0.13	0.02	1.17	0.00	-	-	1.51
Esso/Exxon	0.00	0.01	0.30	3.13	0.05	0.11	0.01	1.25	5.53
Norsk Hydro	-	-	0.76	0.77	1.65	0.63	0.56	0.27	4.64
Phillips	0.02	0.00	0.29	0.34	0.86	0.12	-	-	1.63
Saga	-	-	0.29	0.04	1.65	0.37	0.07	-	2.42
Total	2.12	0.53	8.04	5.84	6.07	1.90	2.83	1.66	

# Tested hypotheses

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Difference in success rate from the overall rate for a particular company over the time is entirely due to chance.

	<i>P</i>
Shell	0.8523
Amoco	0.3407
Den norske	0.3707
Elf	0.3955
Esso/Exxon	0.9342
Norsk Hydro	0.9511
Phillips	0.4503
Saga	0.5931

Variation in success rates between companies within a given 5-year period is entirely due to chance.

Period	<i>P</i>
1966–1970	0.5302
1971–1975	0.3940
1976–1980	0.5936
1981–1985	0.8840
1986–1990	0.6670
1991–1995	0.3227
1996–2000	0.8209
2001–2005	0.4902
2006–2010	0.5259

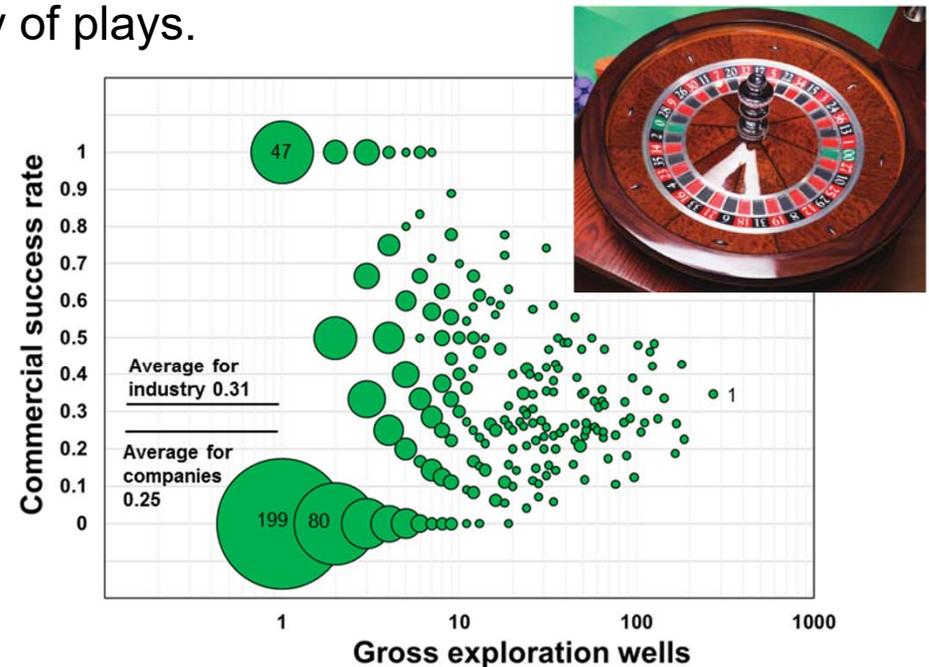
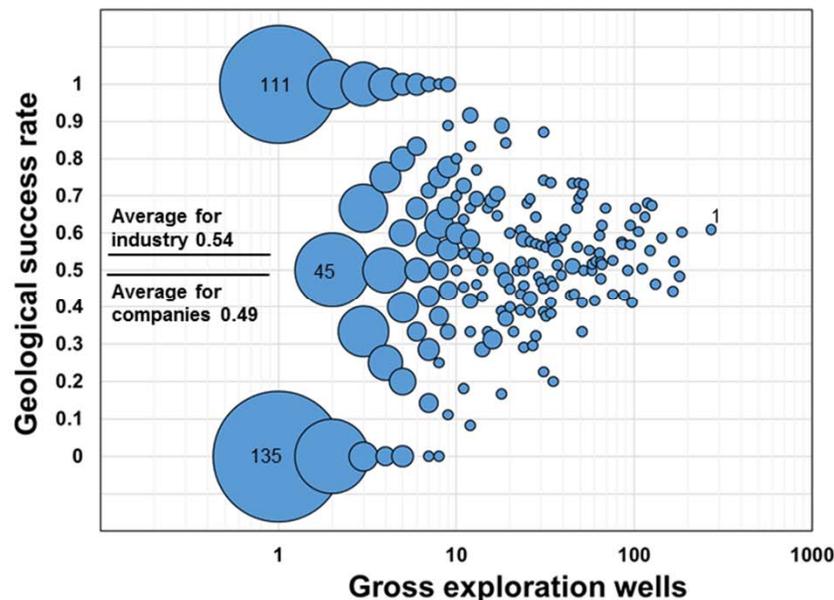
- *P*-values are proportions of simulated data sets for which the sum of  $z^2$  values was greater than that in the real data.
- Reject hypothesis if its *P*-value is  $<0.05$ .

***Both hypotheses are consistent with the data***

# Evidence of luck in global exploration

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- 733 companies participated in 8,096 gross (3,258 actual) exploration wells completed in 2008-2017 across a variety of plays.



Data from Wildcat database (Westwood Energy)

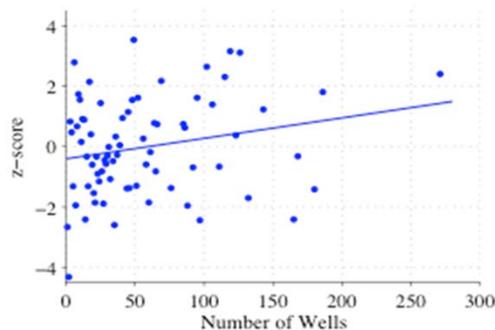
Milkov and Navidi (2019)

# More drilling leads to better success rates, but the signal is weak

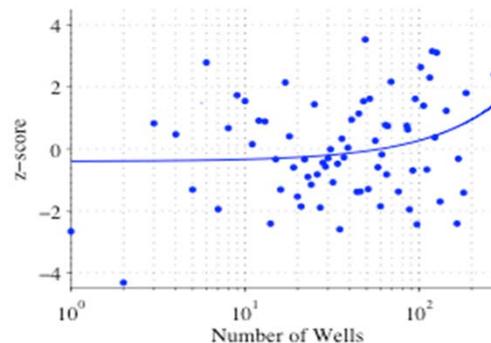
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- Geological success rate tends to be greater for companies that participate in more wells.

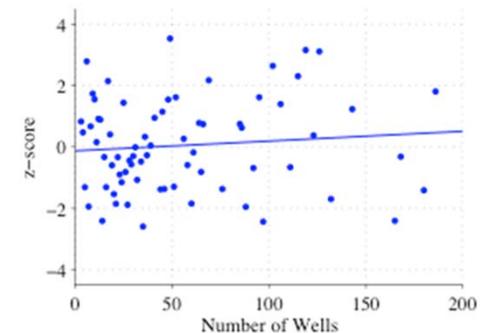
1 or 2 wells (n=355): 0.43    3+ wells (n=378): 0.54    271 wells (n=1): 0.61



1-271 wells  
Positive correlation with  $r=0.222$   
(small, but statistically significant,  $P=0.027$ )



1-271 wells  
Log scale for wells



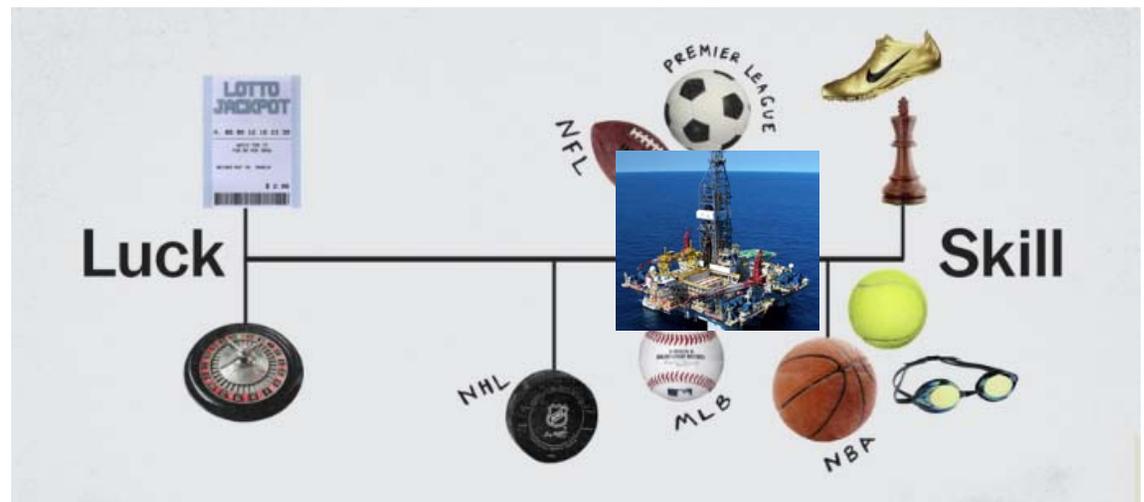
3-186 wells  
Positive correlation with  $r=0.099$   
(not statistically significant,  $P=0.205$ )

Milkov and Navidi (2019)

# Where is exploration on the luck-skill continuum?

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- Compute variance that would be expected from luck alone as a proportion of the observed variance.
- The sum of  $z^2$  scores is the observed variance for technical (191) and commercial (291) success rates.
- If all companies were equally skilled, then the expected sum of  $z^2$  scores would be about 74 (the number of categories describing companies drilling the same number of wells).

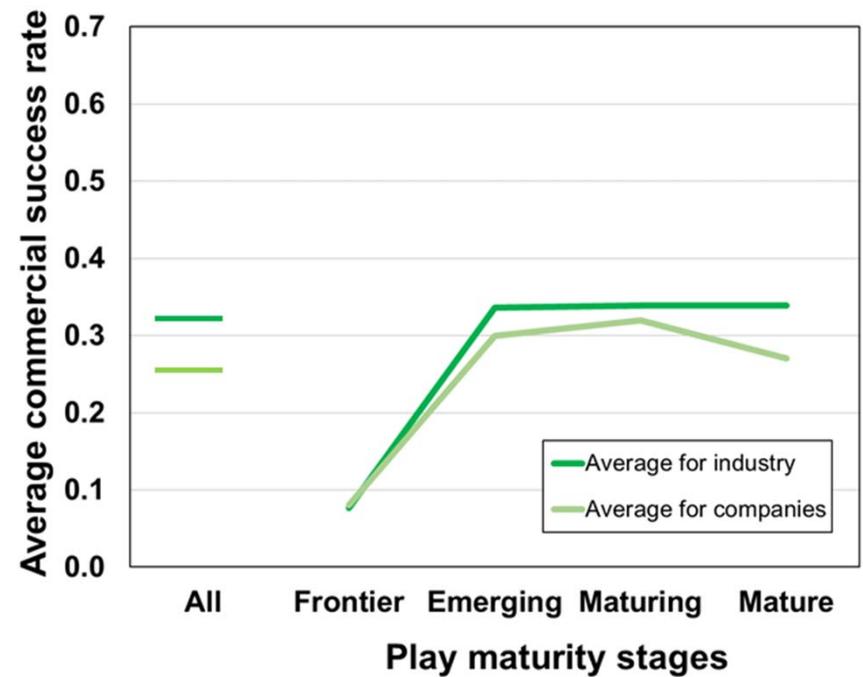
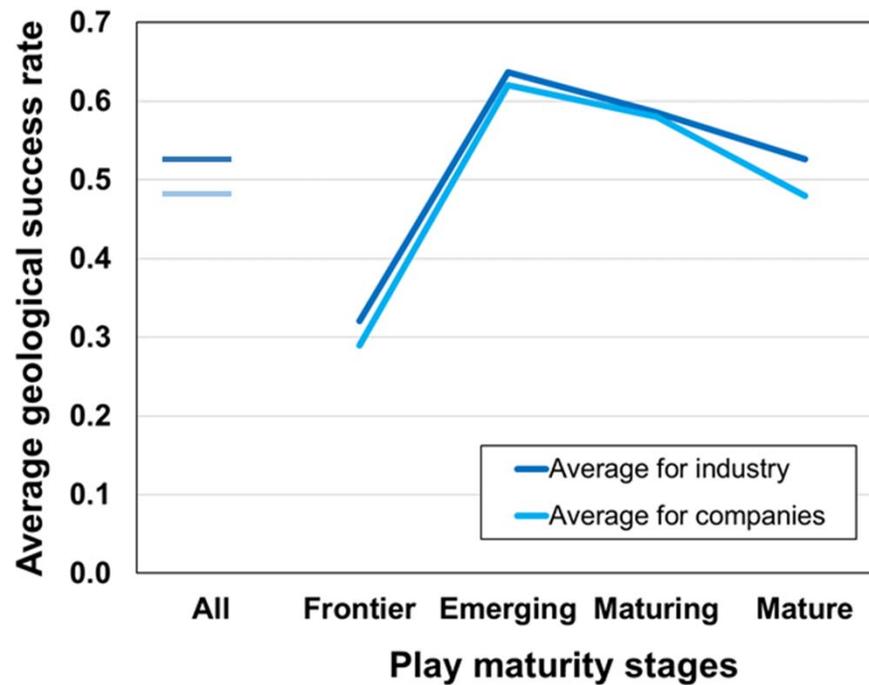


The proportion of variance due to luck:

- Geological success:  $74/191 = 0.39$
- Commercial success:  $74/291 = 0.25$

# Success rates across play maturity stages

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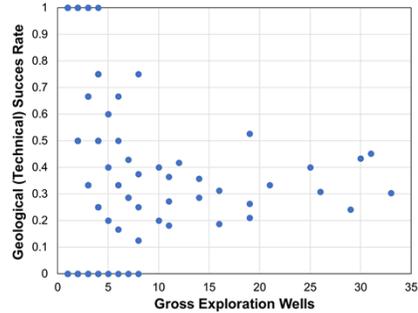
Data from Wildcat database  
(Westwood Energy)

Milkov and Navidi (2019)

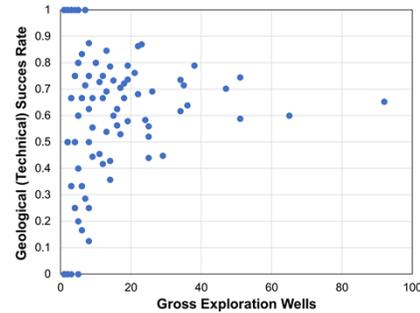
# Success rates vs gross wells across play maturity stages

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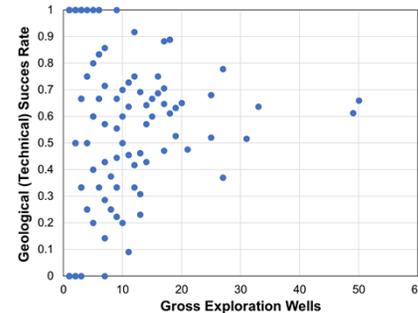
### Frontier



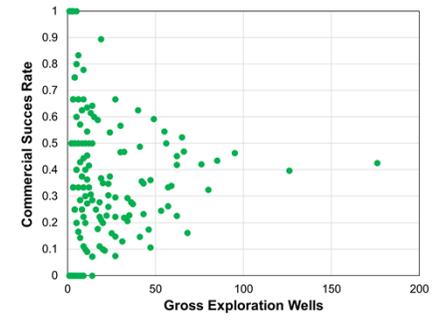
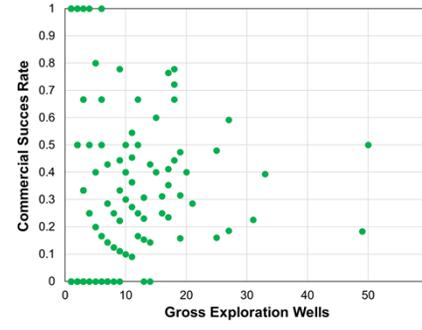
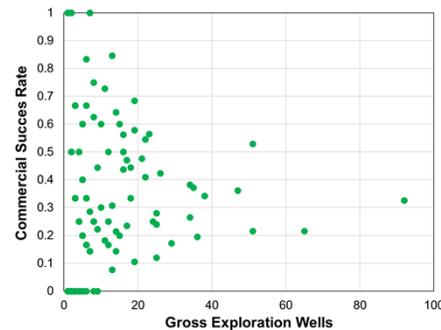
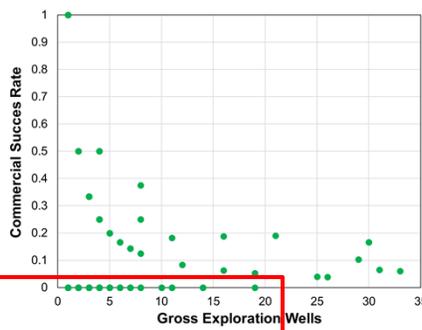
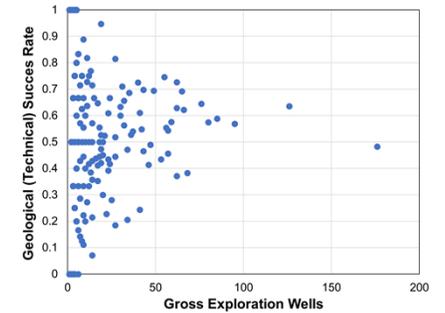
### Emerging



### Maturing



### Mature

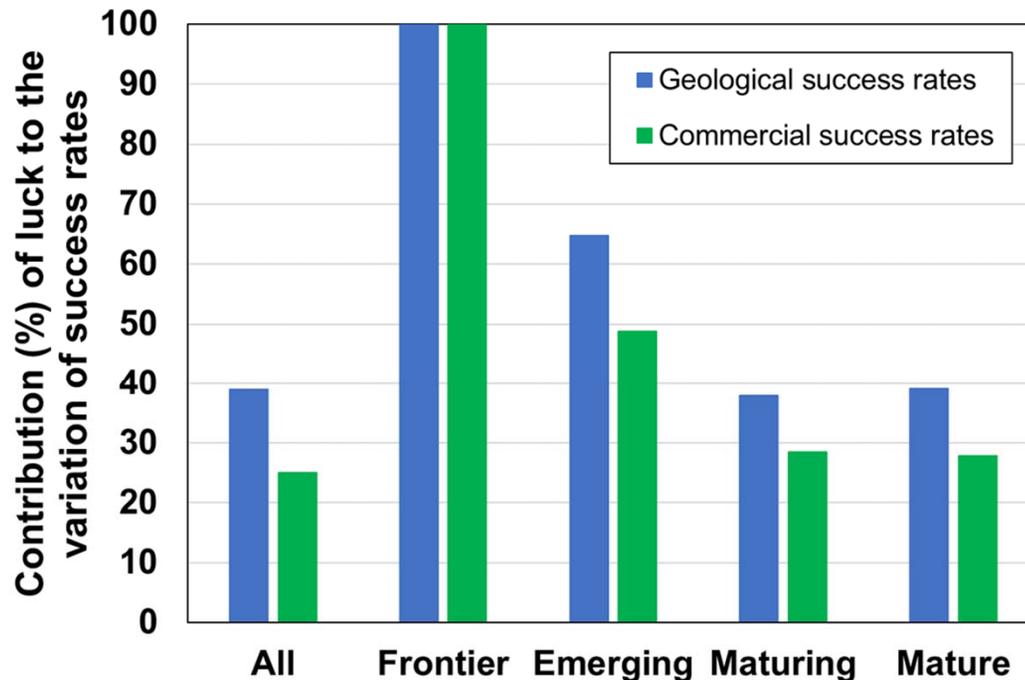


Data from Wildcat database (Westwood Energy)

Milkov and Navidi (2019)

# Role of luck across play maturity stages

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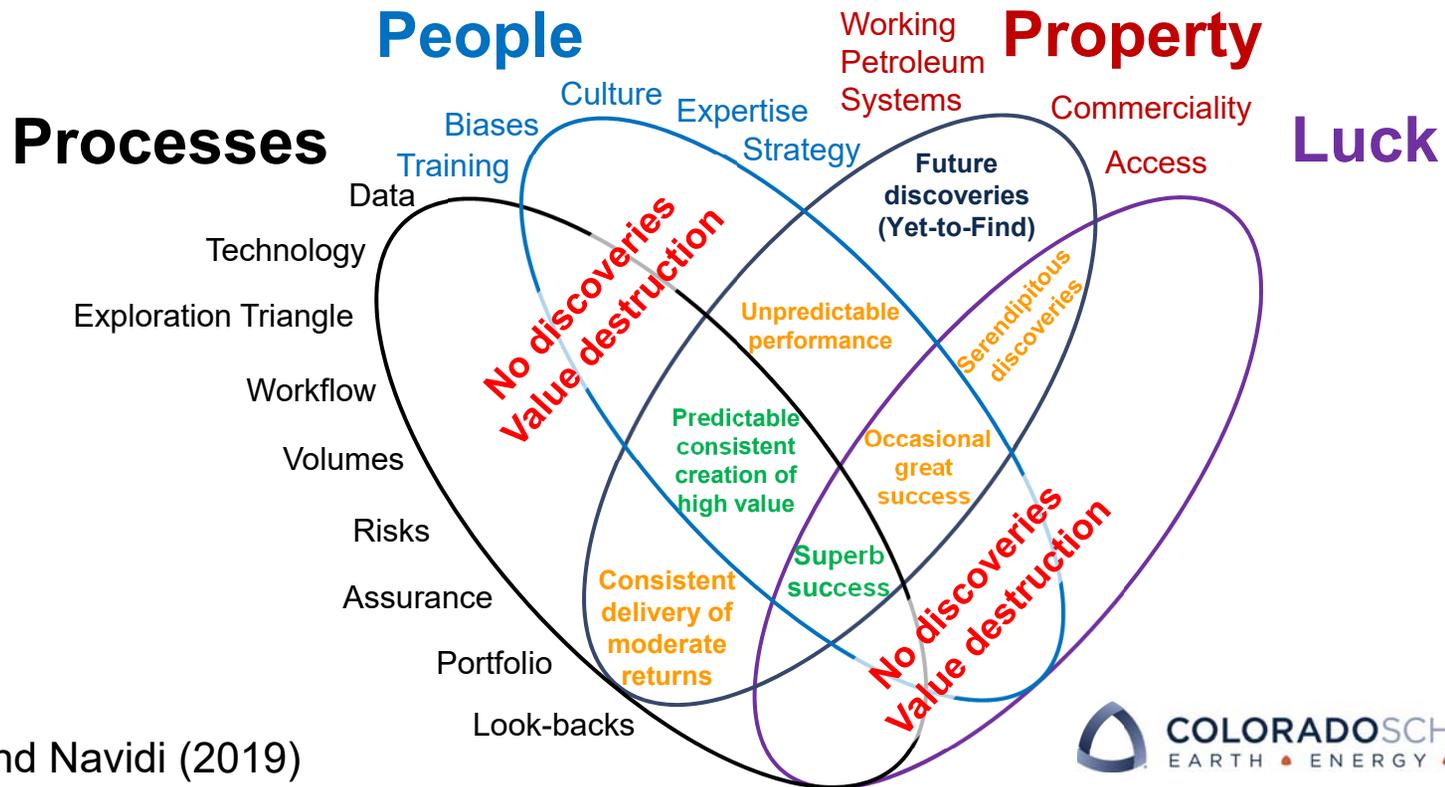


- In frontier plays, exploration success is essentially random:
  - Many unknowns,
  - Companies have similar skills.
- As plays mature, the skill becomes more important.

Milkov and Navidi (2019) **Play maturity stages**

# Exploration success equation

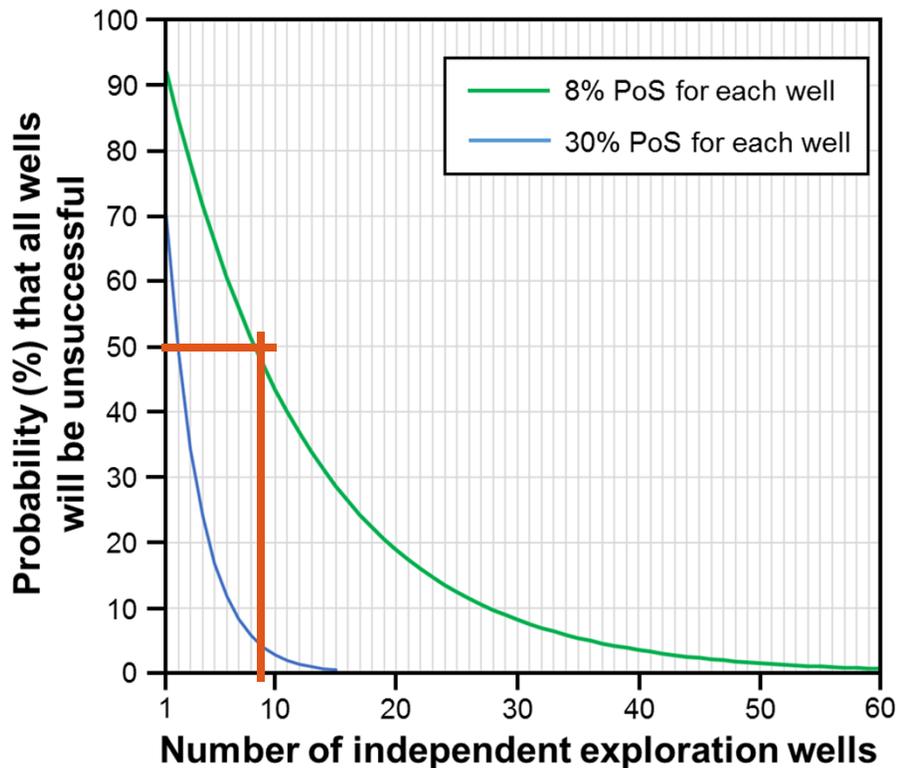
34



Milkov and Navidi (2019)

# Implications for investors: Have realistic (probabilistic) expectations

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## Results from 2008-2017

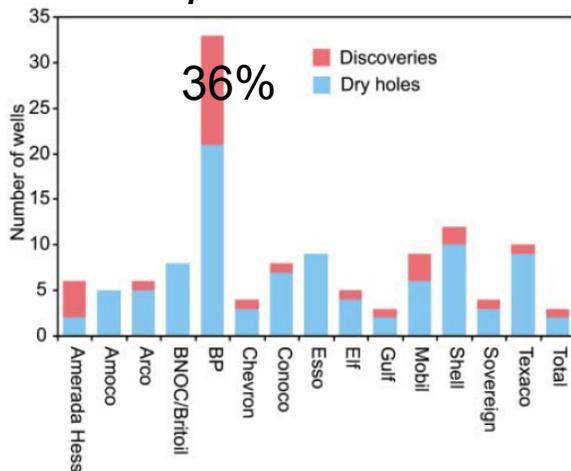
Company	Gross Frontier Wells	Commercial Discoveries
BP	14	0
Petronas	19	0
Repsol	25	1
Total	26	1
Avner	1	1
Pearl	1	1

# Implications for strategies: Change plays carefully

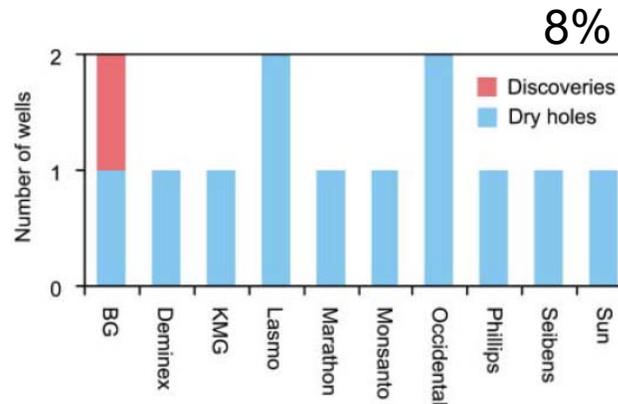
36

## Exploration success rates, West of Shetland

*Operators with 3 or more exploration wells*



*Operators with 1 or 2 exploration wells*



Loizou (2005)

- Skill is relatively more important than luck in maturing and mature plays.
- Play-specific skill may not be easy or fast to obtain or transfer.
- Strategic considerations.

# Implications for performance management: Appreciate the role of luck

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		Outcome	
		Dry Hole	Discovery
Process	Shallow	Failure: Criticize and Fix	Just Good Luck: Stop Praising
	Deep	Smart Test but Bad Luck: Praise, Learn, Repeat	Success: Reward and Repeat

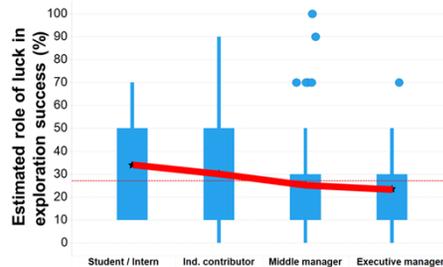
Inspired by  
Adam Grant (2017)

- Good outcome from good process may not happen in every exploration well, but it will happen over sufficiently large number of wells.
- Maintain good process, stay focused, have and communicate realistic expectations.

# Implications for managers: Focus on the process

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- Be humble.

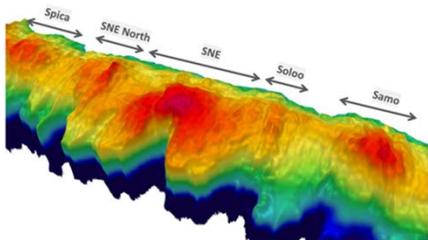


**Ensure the long run!!**

- Reduce the role of luck in exploration:
  - ▣ Maximize company's exposure to opportunities.
  - ▣ Enable geoscientists with data, technology and knowledge.
  - ▣ Deploy consistent and unbiased process of opportunities evaluation.
  - ▣ Keep track record of forecasts versus results, use learnings in new evaluations.
- Culture – measure and reward forecasting abilities, not just the outcome.

# Implications for individual explorers: Being wrong is expected

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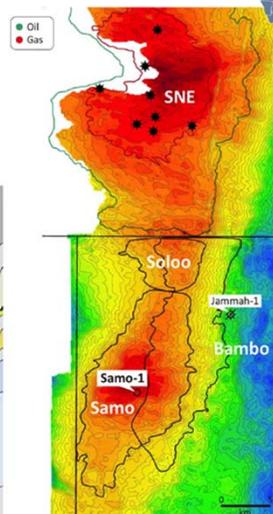
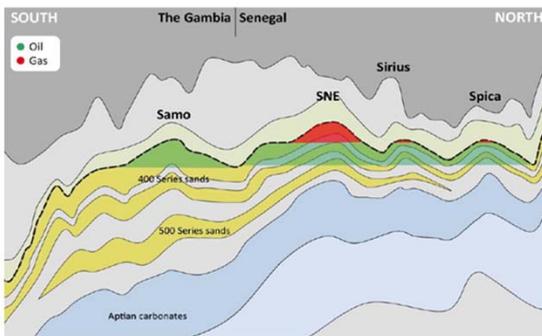


- On trend with SNE
- Key reservoir drilled by 9 wells with 100% success
- 50% geol. PoS



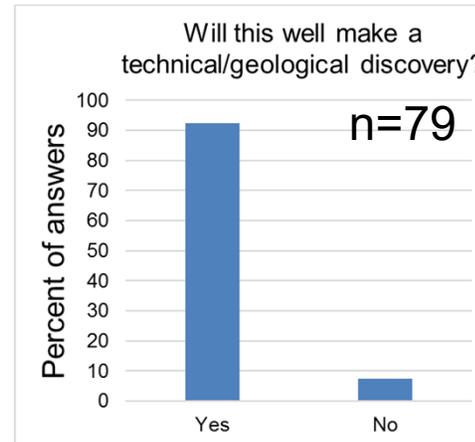
Samo Prospect Volumes*	Low estimate (P90)	Best estimate (P50)	High estimate (P10)
	335	825	1,713

Source: FAR



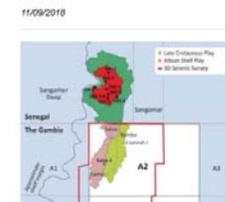
\*Seismic Data

- Exploration, especially in the frontier areas, is the business of being mostly wrong.
- There are factors beyond your visibility and control.



**Offshore**

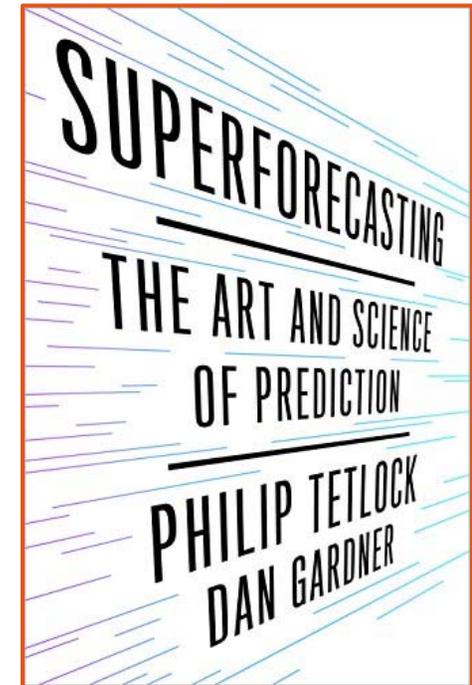
**Offshore The Gambia well fails to deliver**



# Implications for individual explorers: Be better forecasters

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- Focus less on the binary outcomes of each well and more on the comparison of your predictions of well results with the outcome.
- Good long run forecasting is a true measure of skill.
- Forecasting abilities can be developed and cultivated.



# Main takeaways

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- Recognize the role of luck in petroleum exploration.
- Focus on the process. Ensure long run.
- Hone your forecasting skills.

**Property + People + Process + Luck**

# Questions / comments?

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