Summary and Results of the 2020 NPD/FORCE machine learning competition

Peder Aursand (**AkerBP**), Peter Bormann (**ConocoPhillips**), Petter Dischington (**NPD**), Fahad Dilib (**Equinor**), Surender Manral (**Schlumberger**)

Motivation

Highly successful SEG ML contest in 2016 (Hall& Hall, 2016)

- 40 teams
- 8 training wells
- 2 test wells and no blind wells

- 136 citations in google scholar
- Dataset not entirely public domain

- Demonstrates the need for open data
- Demonstrated that there is an increasing skill pool of geo-datascientists

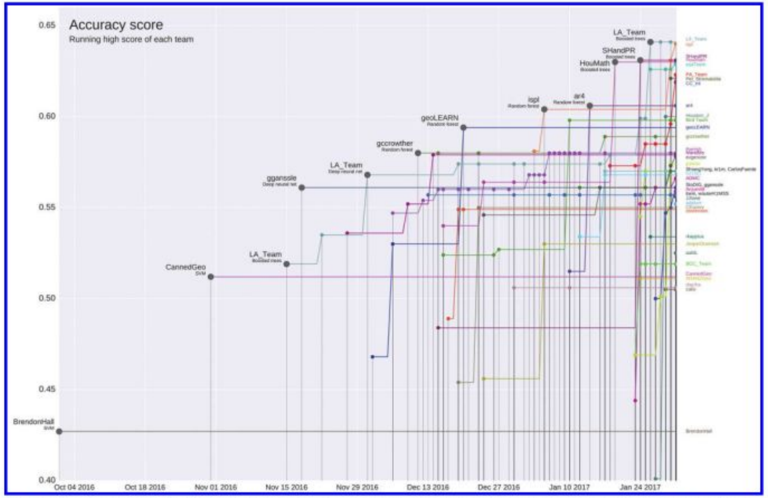
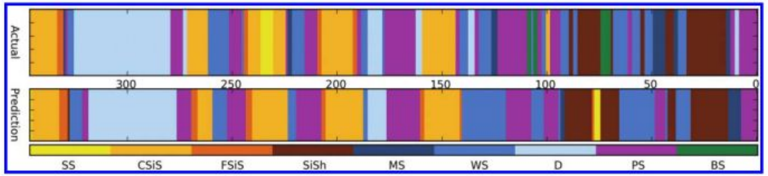


Figure 1. The progress over time of entries to the contest. Each team is represented by a colored line; the line shows the team's highest score up to that point. Each entry is represented by a vertical line and a dot. Changes in the first-place position are shown by a larger gray dot, annotated with the name of the team and the type of model they used. The scores shown are the deterministic scores. The final positions shown in Table 1 were determined stochastically.



FORCE competition 2020 - GOALS

- Competition on well log data (lithology) and seismic data (faults)
- Global // online // virtual // free of charge

- Data needs to be open source
- Codes need to be public (well logs)
- Provide a legacy database

- Focus on geoscience domain knowledge holders
- Access and connect an increasing skill pool of geodatascientists

- Create an algorithm benchmark for the future





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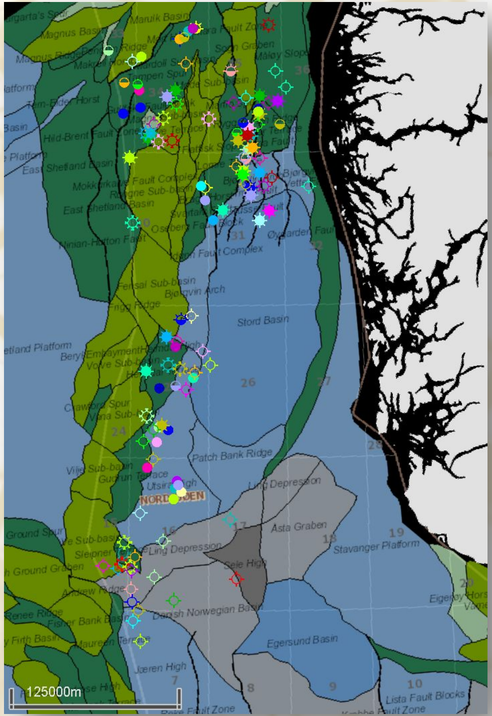
FORCE competition 2020 –Datasets

- **Seismic data from Geoscience Australia** - via ConocoPhillips company
- **Well dataset from Diskos (NOLD 1.0 License)**
  - No lithology interpretation available
  - Well logs spliced but of very different quality per well
  - Well formation tops OK
- **Need to get funding to create a consistent lithology dataset**
  - Start up funding from FORCE (200knok)
  - Supplemented by sponsors (260knok)
  - Need for a scoring platform

XEEK Agile*



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FORCE competition 2020 – Lithology Dataset

i2G™

EXPLOCROWD

- Well dataset from Diskos (NOLD 1.0 License)

- Lithology interpretation label generation
  - Used **Explocrowd** for creation of lithology interpretation
  - Aware of interpretation bias
  - Hope for consistent interpretations bias
  - 250knok cost
  - 14 wells from **I2G** (Vietnam) -free

  - Use of cuttings, complogs, inhouse data

Log Name	Log Description
FORCE_2020_LITHOFACIES_CONFIDENCE	Qualitiative measure of interpretation confidence
FORCE_2020_LITHOFACIES_LITHOLOGY	Interpreted Lithofacies
RDEP	Deep Reading Restitivity measurement
RSHA	Shallow Reading Restitivity measurement
RMED	Medium Deep Reading Restitivity measurement
RXO	Flushed Zone Resistivity measurment
RMIC	Micro Resisitivity measurment
SP	Self Potential Log
DTS	Shear wave sonic log (us/ft)
DTC	Compressional waves sonic log (us(ft)
NPHI	Neutron Porosity log
PEF	Photo Electric Factor log
GR	Gramma Ray Log
RHOB	Bulk Density Log
DRHO	Density Correction log
CALI	Caliper log
BS	Borehole Size
DCAL	Differential Caliper log
ROPA	Average Rate of Penetration
SGR	Spectra Gamma Ray log
MUDWEIGHT	Wheight of Drilling Mud
ROP	Rate of Penetration
DEPTH_MD	Measured Depth
x_loc	X location of sample
y_loc	Y location of sample
z_loc	Z (TVDSS) Depth of sample

Sandstone
Sandstone/Shale
Shale
Marl
Dolomite
Limestone
Chalk
Halite
Anhydrite
Tuff
Coal
Crystalline Basemen

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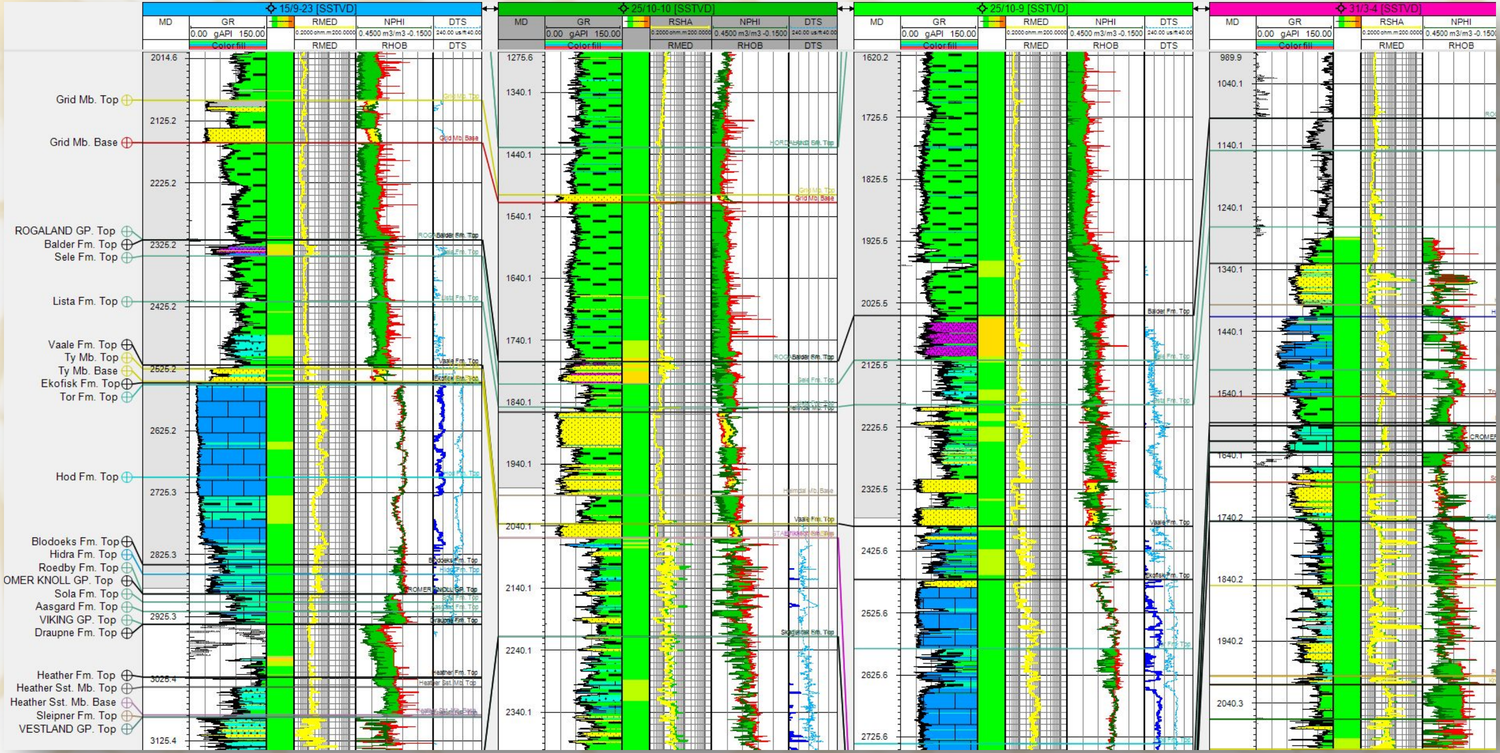
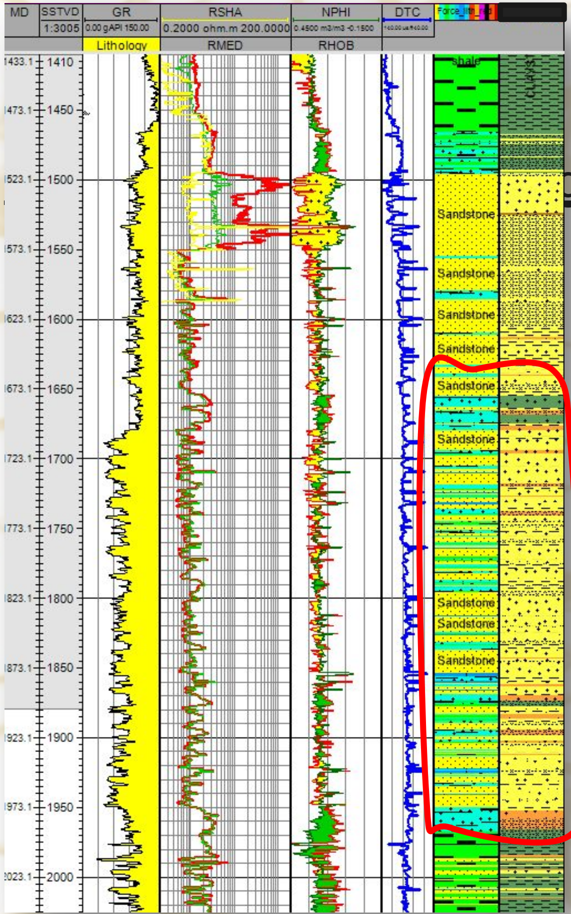
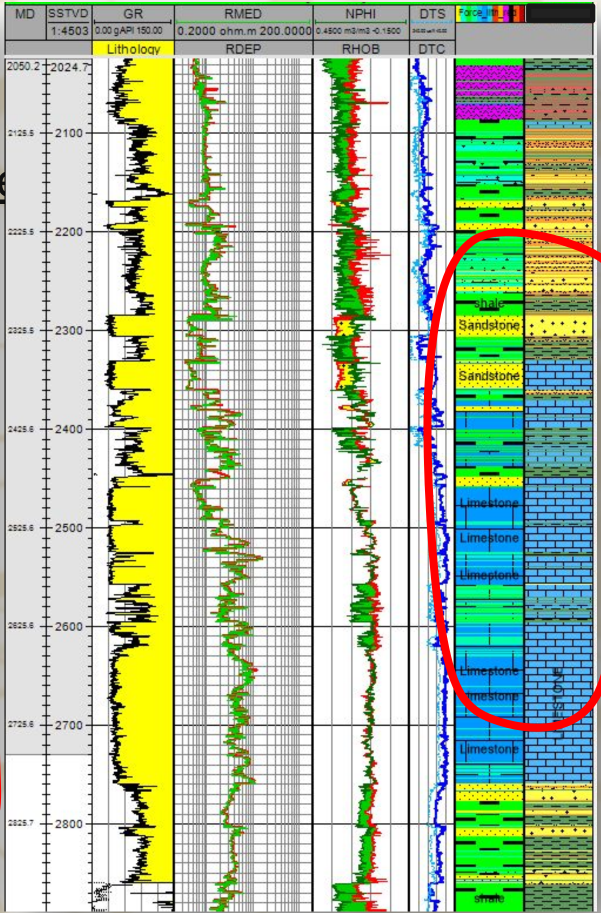
FORCE competition 2020 – Well log competition

- 98 interpreted wells released as training data
- 10 test wells (test the prediction)
- 10 blind data (score the final submitted models)
- Lithology and confidence interpretation



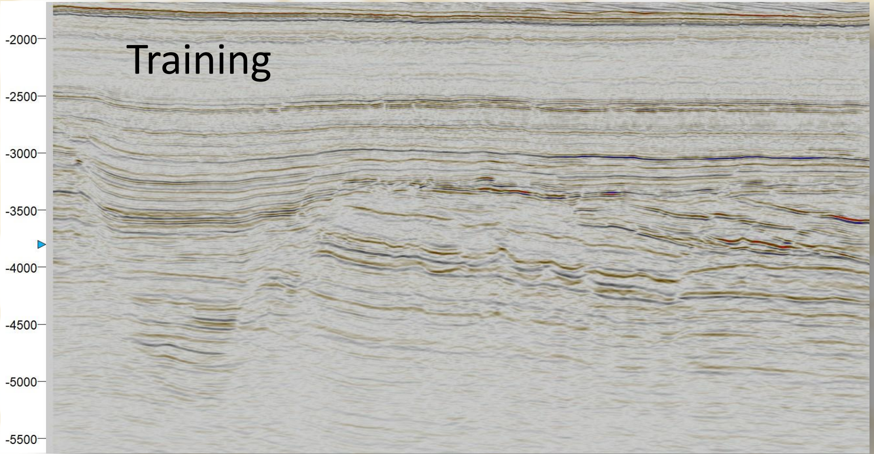
FORCE competition 2020 - Dataset interpretation

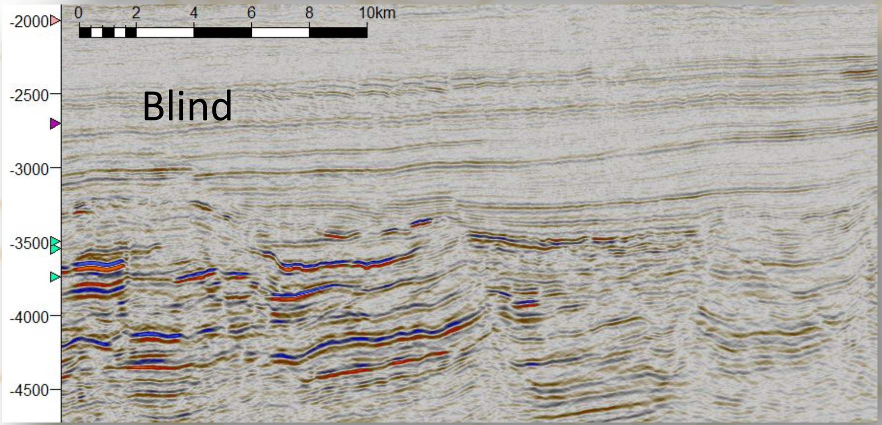




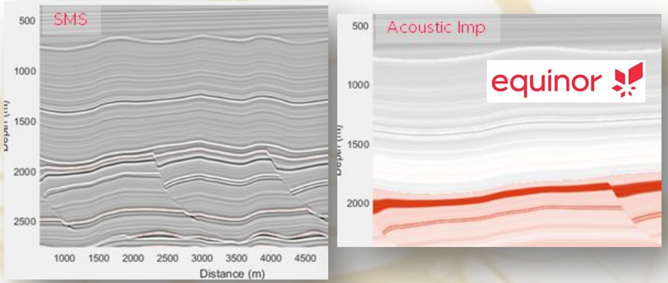
- Lithology will always be an interpretation
- Cuttings help but do not provide the final answer
- Perhaps one needs to crowd source weighted interpretation

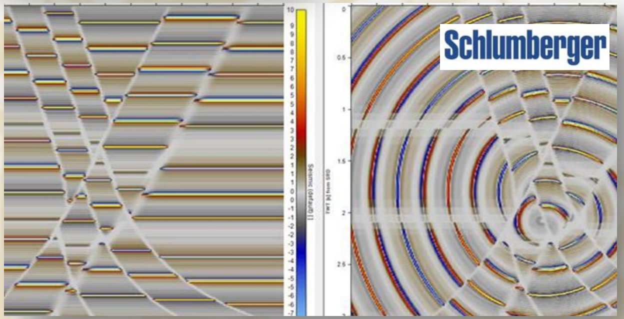
FORCE competition 2020 – Seismic datasets





- 3 month to assess together with synthetic models





- 12h to score and return result
- No need to disclose code

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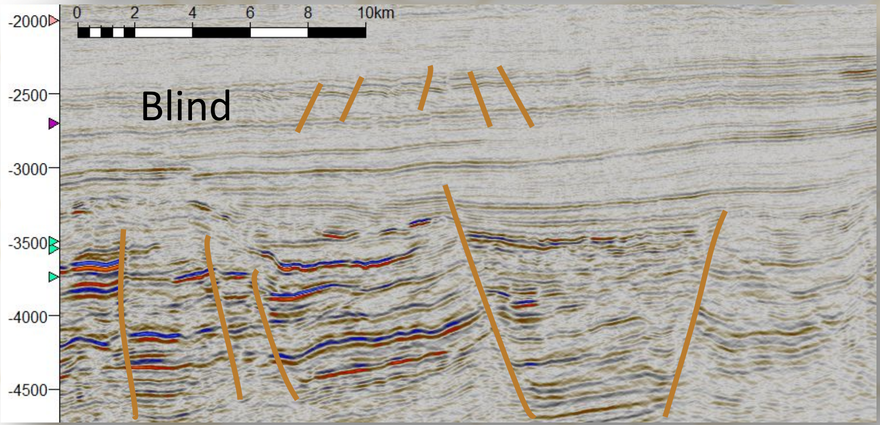
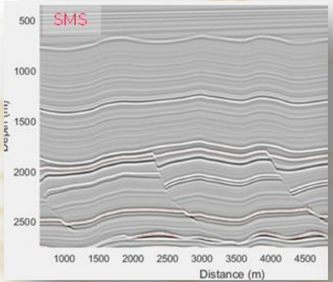
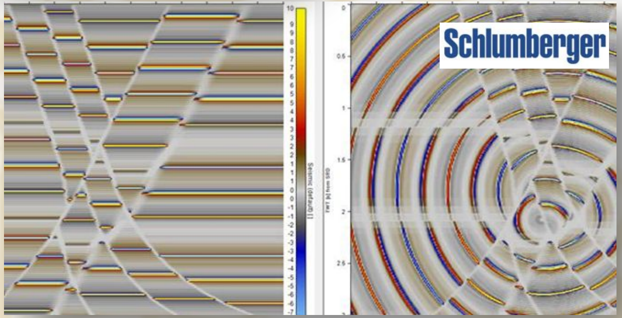
FORCE competition 2020 – Seismic datasets



- 3 month to assess together with synthetic models





- <u>12h</u> to score and return result
- No need to disclose code

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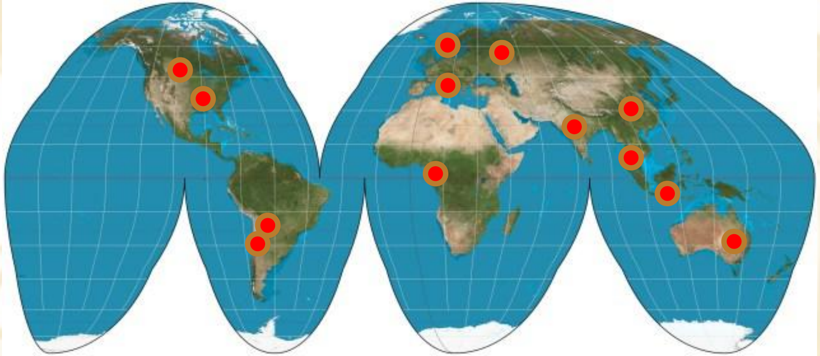
Who participated in these comeptitions

GIR is a research group from Universidade Estadual do Norte Fluminense (UENF), located in Macaé, Brazil.

We are Team H3G (**H**arry Brandsen, **H**aoyuan Zhang, **H**elena Nandi Formentin, **G**regory Barrere) from Equinor.



Applied Computational Intelligence Laboratory (ICA).

The ISPL_Team is made up of researchers and PhD students from the Image and Sound Processing Laboratory (ISPL) of the Politecnico di Milano (Italy

400 teams and over 1000 individuals globally

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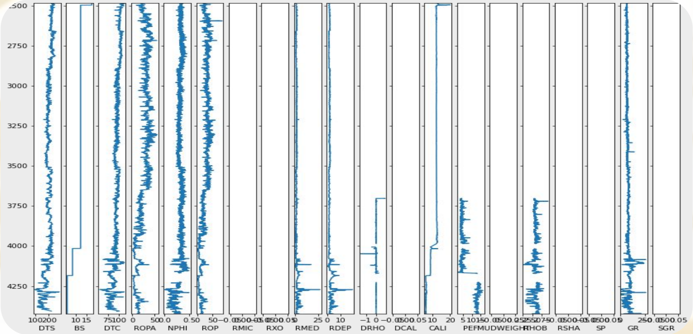
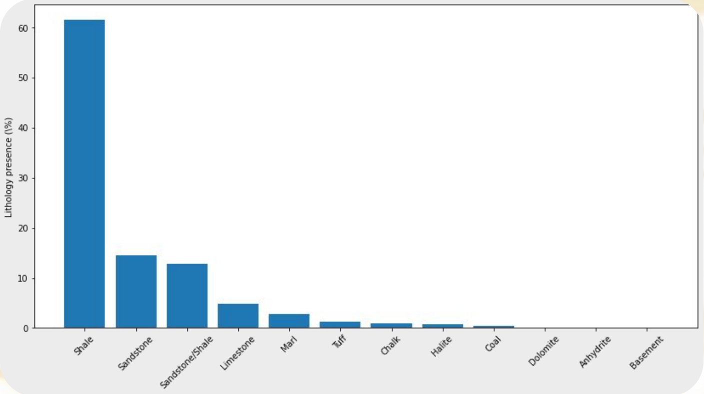
What made this a different ML well dataset and competition?

1. Realistic well data





2. Geologically motivated scoring

label \ prediction	Sandstone	Sandstone/Shale	Shale	Marl	Dolomite	Limestone	Chalk	Halite	Anhydrite	Tuff	Coal	Crystalline Basement
Sandstone	0	2	3.5	3	3.75	3.5	3.5	4	4	2.5	3.875	3.25
Sandstone/Shale	2	0	2.375	2.75	4	3.75	3.75	3.875	4	3	3.75	3
Shale	3.5	2.375	0	2	3.5	3.5	3.75	4	4	2.75	3.25	3
Marl	3	2.75	2	0	2.5	2	2.25	4	4	3.375	3.75	3.25
Dolomite	3.75	4	3.5	2.5	0	2.625	2.875	3.75	3.25	3	4	3.625
Limestone	3.5	3.75	3.5	2	2.625	0	1.375	4	3.75	3.5	4	3.625
Chalk	3.5	3.75	3.75	2.25	2.875	1.375	0	4	3.75	3.125	4	3.75
Halite	4	3.875	4	4	3.75	4	4	0	2.75	3.75	3.75	4
Anhydrite	4	4	4	4	3.25	3.75	3.75	2.75	0	4	4	3.875
Tuff	2.5	3	2.75	3.375	3	3.5	3.125	3.75	4	0	2.5	3.25
Coal	3.875	3.75	3.25	3.75	4	4	4	3.75	4	2.5	0	4
Crystalline Basement	3.25	3	3	3.25	3.625	3.625	3.75	4	3.875	3.25	4	0

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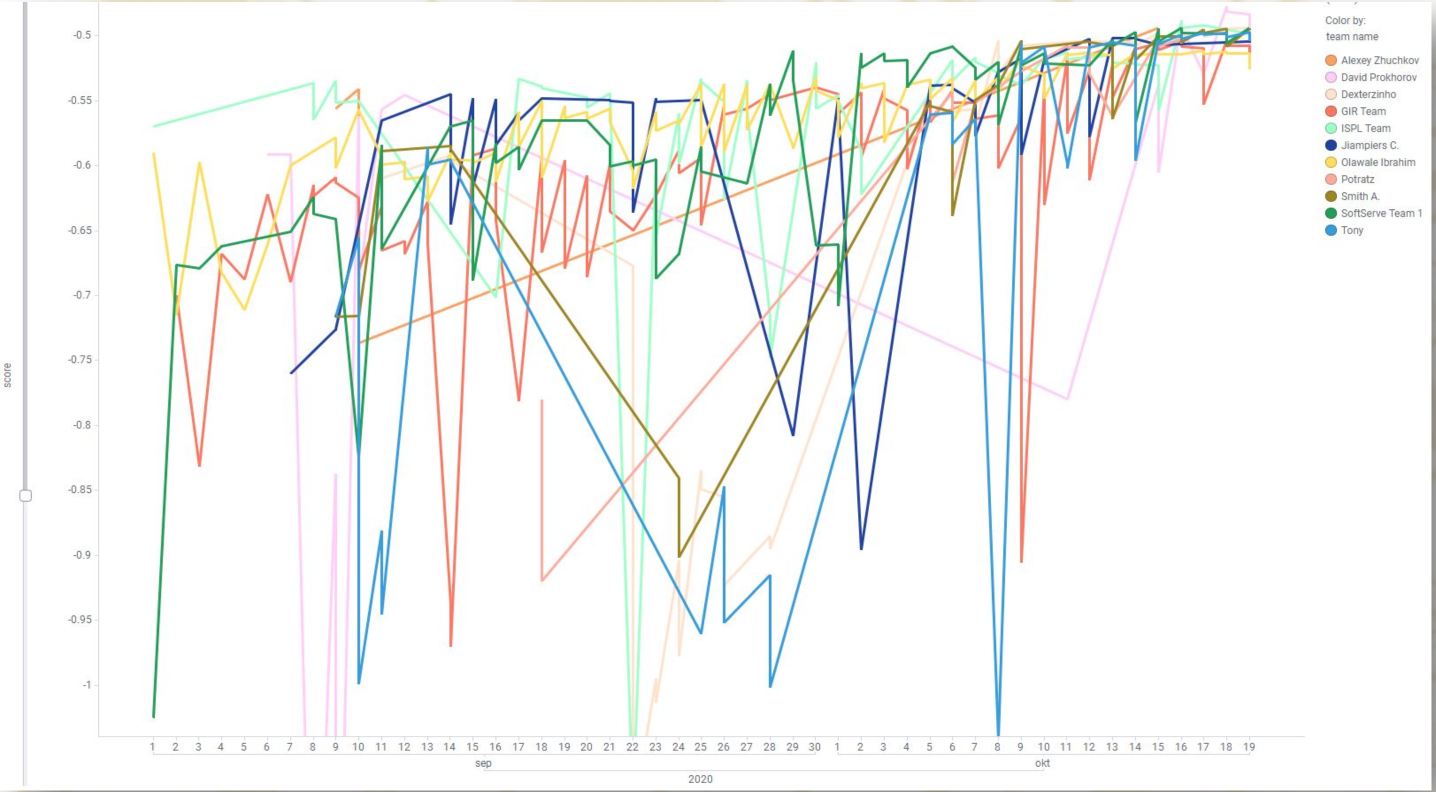
The lithology prediction leaderboard



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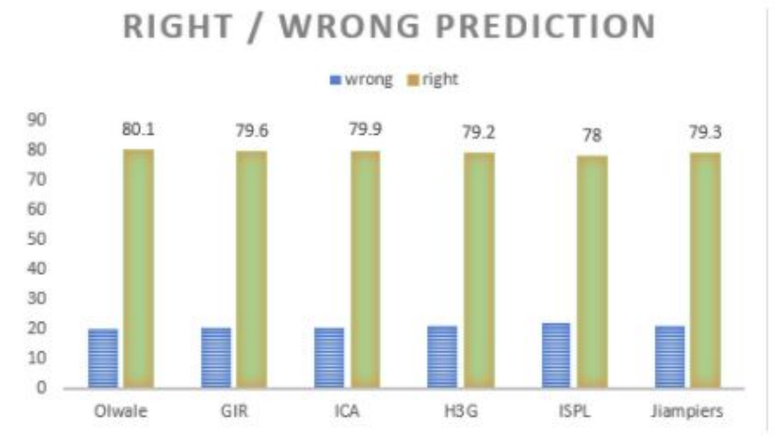
How did the lithology competition go?

- 329 teams signed up, 148 submitted
- Extremely close results
- Solid preprocessing and feature engineering wins over facy ML methods
- No mind-blowing accuracy, but in some cases ML predictions may have uncovered errors in official interpretation

Team	Leaderboard score	Leaderboard rank	Final test score	Final rank
Olawale Ibrahim	-0.5118	24	-0.4690	1
GIR Team	-0.5037	11	-0.4792	2
Lab.ICA-Team / Smith A.	-0.4943	6	-0.4954	3
H3G (Haoyuan Zhang, Harry Brandsen, Gregory Barrere, Helena Nandi Formentin)	-0.509	17	-0.5045	4
ISPL Team	-0.4885	2	-0.5084	5
Jiampiers C.	-0.5014	9	-0.5087	6
José Bermúdez	-0.5052	14	-0.5091	7
Bohdan Pavlyshenko	-0.5112	22	-0.5171	8
Jeremy Zhao	-0.5264	31	-0.5173	9
Campbell Hutcheson	-0.505	13	-0.5221	10
David P.	-0.4775	1	-0.5256	11
SoftServe Team	-0.4936	3	-0.5263	12
Dapo Awolayo	-0.5121	25	-0.9441	13



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Lithology: The winning recipe (top three)

Machine learning algorithm:

- XGBoost (gradient boosting)

Model selection:

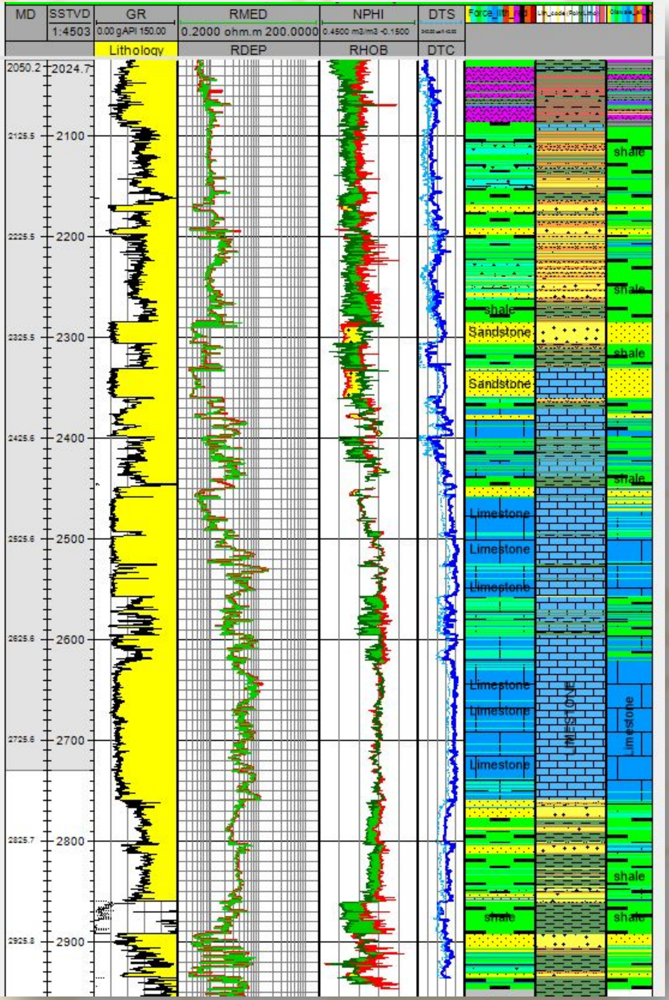
- Stratified KFold cross-validation

Pre-processing:

- Dropping rare curves
- Imputing missing intervals
- Basic z-score normalization

Add non-local features:

- Compute gradient of logs
- Min/max/mean of a log in a depth window



FORCE competition 2020 – Results and interpretation scores

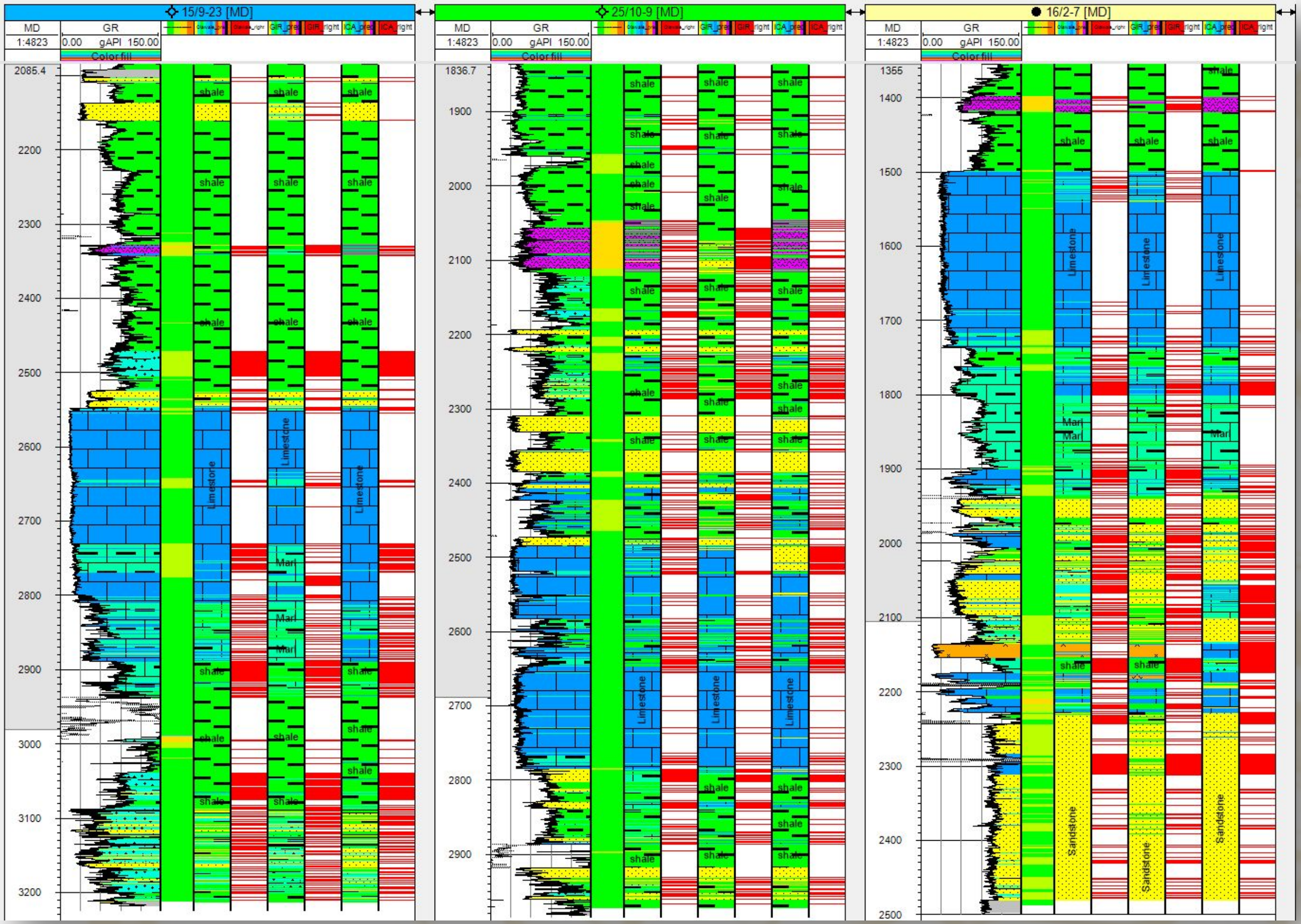
1st Olawale Predicted	Labeled Sandstone	Labeled Sandstone /Shale	Labeled Shale	Labeled Marls	Labeled Dolomite	Labeled Limestone	Labeled Chalk	Labeled Halite	Labeled Anhydrite	Labeled Tuff	Labeled Coals	Labeled Basement
Sandstone	78.5	20.5	1.4	5.5		2.7						
Sandstone /Shale	12.7	55.5	8.3	4.4		0.3				11.9	5.7	
Shale	3.6	14.1	86.3	32.9		2.7	2.4	0.2	1.4	21.0	13.8	
Marl	0.1	7.7	2.0	30.7		11.7	5.1					
Dolomite	0.0		0.2	0.0	5.6	0.1		0.0	18.5			
Limestone	4.1	1.9	1.4	26.2	11.1	60.9	15.6		4.5	3.3		
Chalk	0.5		0.0	0.2		21.1	76.9					
Halite			0.0		27.8	0.1		98.9	1.0			
Anhydrite	0.1		0.0		55.6	0.4		0.9	74.6			
Tuff	0.0		0.3			0.1				63.8		
Coals	0.2	0.3	0.1			0.0					80.5	
Basement												

2ndGIR Predicted	Labeled Sandstone	Labeled Sandstone /Shale	Labeled Shale	Labeled Marls	Labeled Dolomite	Labeled Limestone	Labeled Chalk	Labeled Halite	Labeled Anhydrite	Labeled Tuff	Labeled Coals	Labeled Basement
Sandstone	75.0	24.5	1.5	0.6		2.8					0.8	
Sandstone /Shale	12.8	51.8	6.6	6.6		0.3				5.2	9.2	
Shale	5.0	21.4	87.1	21.7	8.4	2.8	2.6	0.0	1.3	36.2	14.2	
Marl	0.1	1.6	2.2	42.4	1.0	9.5	6.4			0.8		
Dolomite	0.0		0.2	0.1	40.6	0.1			6.0			
Limestone	5.5	0.5	1.4	27.3	6.4	64.2	1.2		8.5	4.6		
Chalk	0.4			1.3		19.7	89.8					
Halite	0.1		0.3		13.4	0.0		98.8	0.2			
Anhydrite	0.1	0.0	0.0		30.2	0.4		1.2	84.0			
Tuff	0.9	0.0	0.6			0.1				53.3		
Coals	0.1	0.2	0.0								75.7	
Basement												

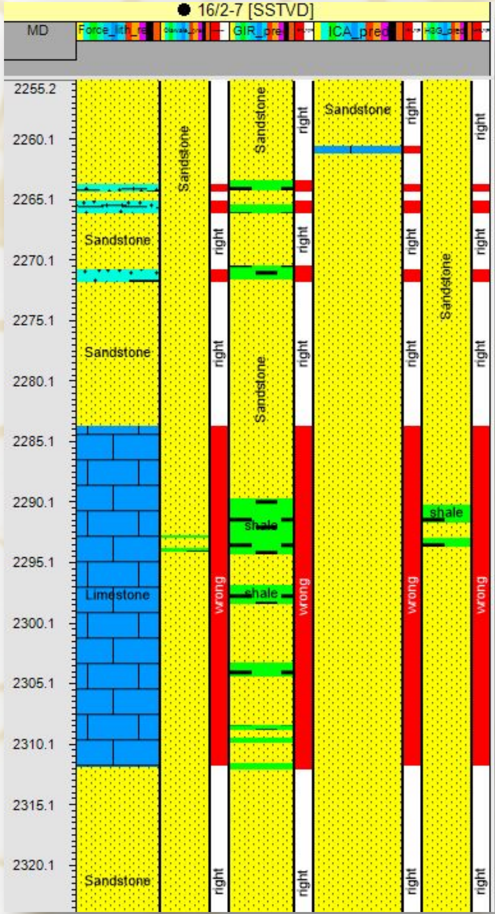
3rd ICA Predicted	Labeled Sandstone	Labeled Sandstone /Shale	Labeled Shale	Labeled Marls	Labeled Dolomite	Labeled Limestone	Labeled Chalk	Labeled Halite	Labeled Anhydrite	Labeled Tuff	Labeled Coals	Labeled Basement
Sandstone	71.3	19.2	2.4	8.6		7.6				0.6		
Sandstone /Shale	15.1	58.6	8.2	2.9		0.7				11.0	10.4	
Shale	4.7	12.9	86.1	22.1		3.0	0.4	0.2	2.1	23.8	18.9	
Marl	1.0	8.8	1.6	48.0		12.8	2.1					
Dolomite	0.0		0.2	0.2		0.3		0.1	20.9			
Limestone	6.2	0.5	1.3	18.1		58.1	17.1			3.3		
Chalk	1.5		0.0	0.0		15.8	80.3					
Halite			0.0			0.0		98.7	1.7			
Anhydrite	0.1		0.0			1.4		1.0	75.4			
Tuff			0.2			0.2				61.2		
Coals	0.1	0.1	0.0								70.7	
Basement												

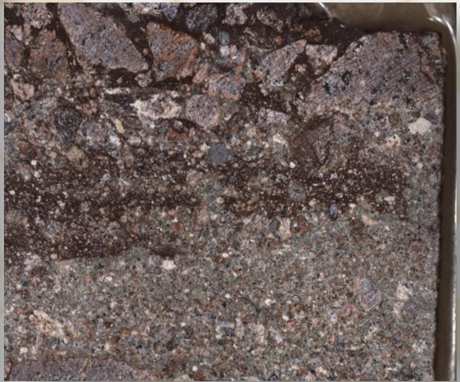
4th H3G Predicted	Labeled Sandstone	Labeled Sandstone /Shale	Labeled Shale	Labeled Marls	Labeled Dolomite	Labeled Limestone	Labeled Chalk	Labeled Halite	Labeled Anhydrite	Labeled Tuff	Labeled Coals	Labeled Basement
Sandstone	79.5	14.4	2.3	2.0		5.1			0.4	0.9		
Sandstone /Shale	11.7	64.4	10.1	6.3		0.8				14.2	7.3	
Shale	3.6	10.3	84.0	43.6		3.1	3.3	0.0	4.0	16.8	14.5	
Marl	0.1	6.5	1.9	31.7		10.6	6.0					
Dolomite	0.1		0.2	0.0	40.0	1.3			2.9			
Limestone	3.6	4.1	1.0	16.2	40.0	60.0	16.6			3.1		
Chalk	1.0		0.0	0.1		15.8	74.0					
Halite	0.0		0.1			0.1		99.2	8.0			
Anhydrite	0.1		0.0	0.0	20.0	2.8		0.7	84.8			
Tuff		0.3	0.3			0.3				65.0		
Coals	0.3	0.0	0.1								78.2	
Basement												

FORCE competition 2020 – Results and interpretation



FORCE competition 2020 – Results and interpretation






NOROG Digital Cuttings Project
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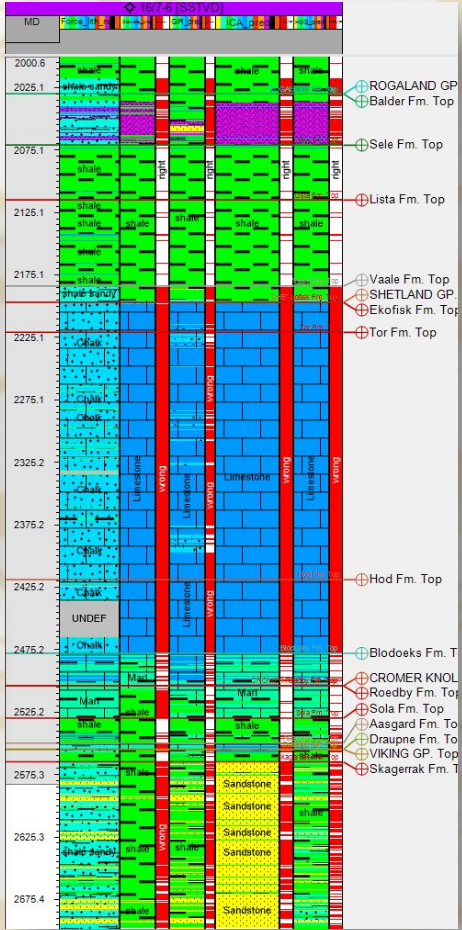
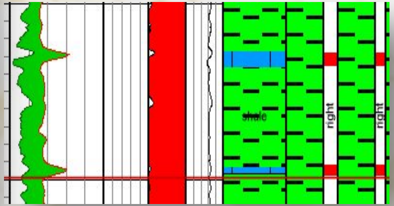
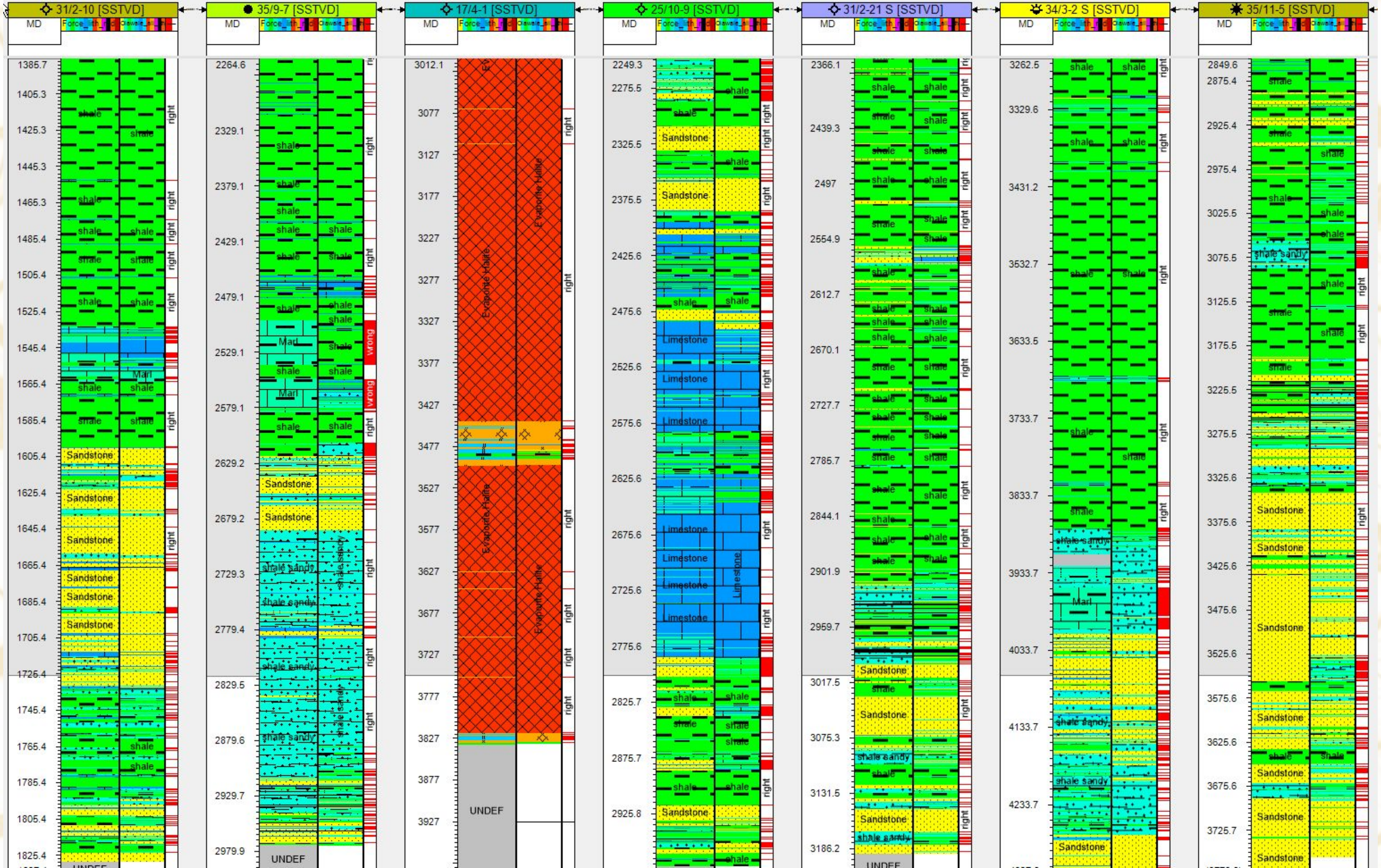
2313m
White Light







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shale
Sandstone
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right
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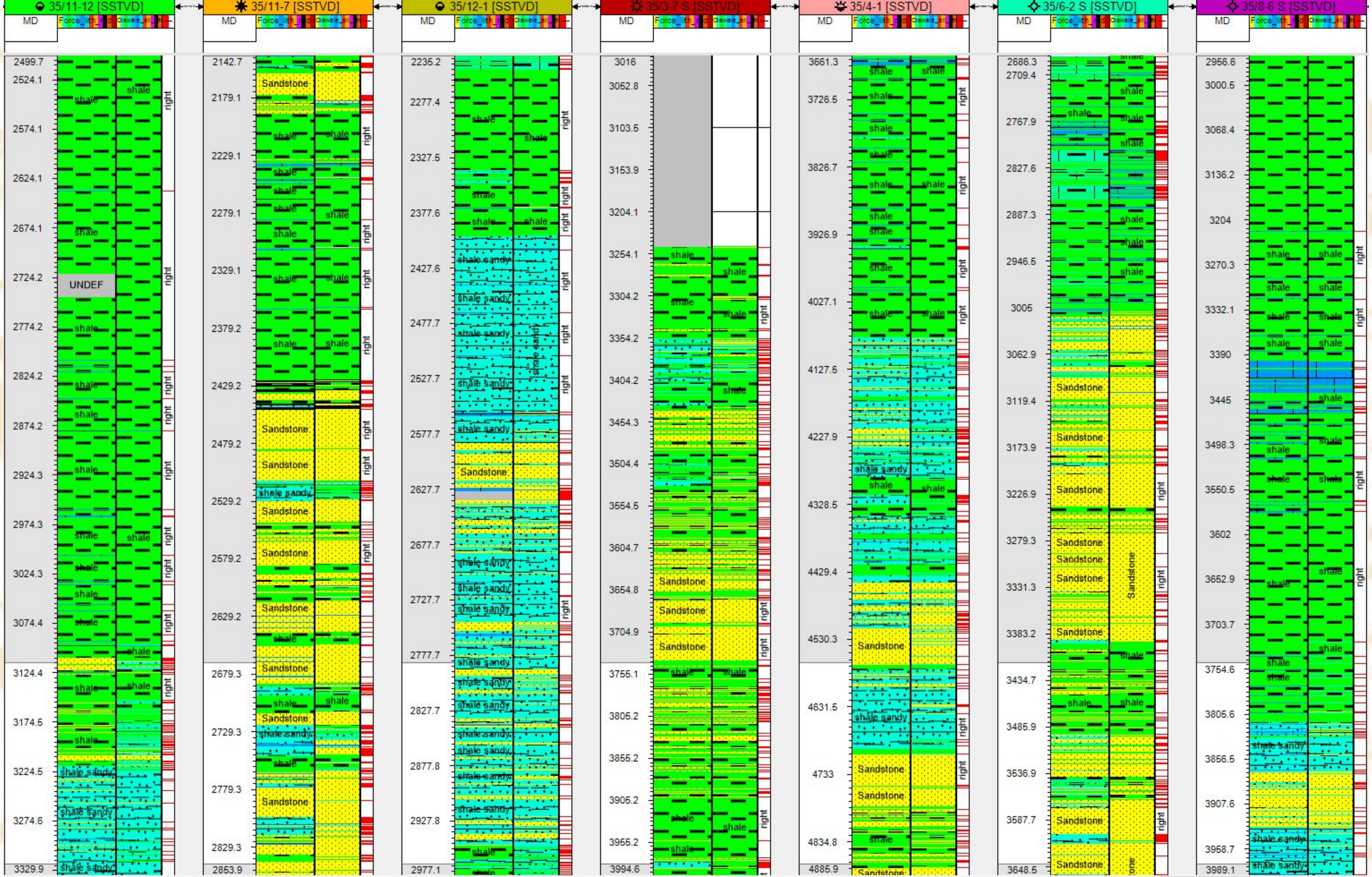
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shale
Sandstone
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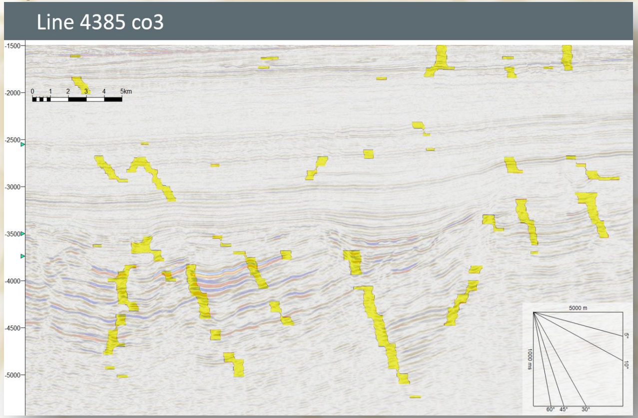
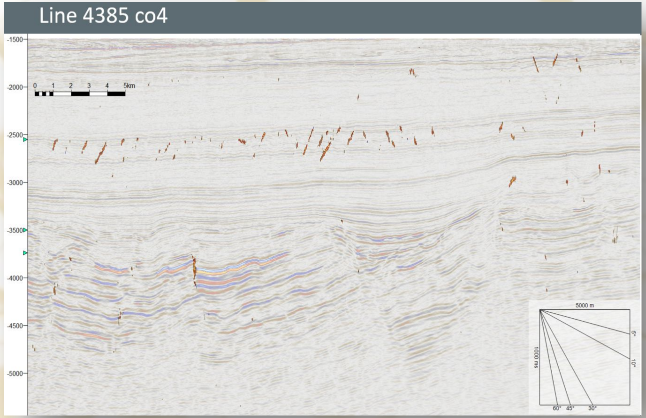
How did the seismic competition go?

- 80 teams signed up
- 7 submitted a results
- No vendor submitted
- Not impressive

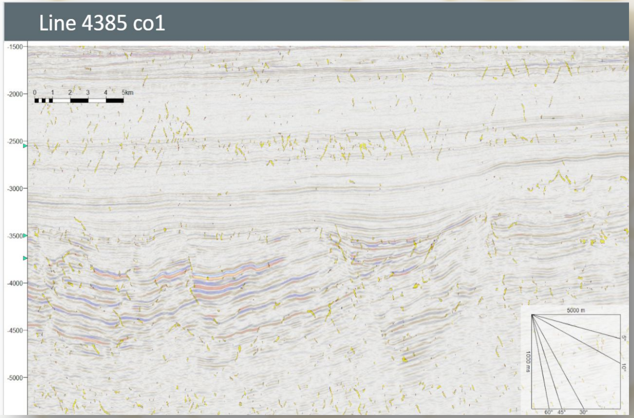
Sparveon



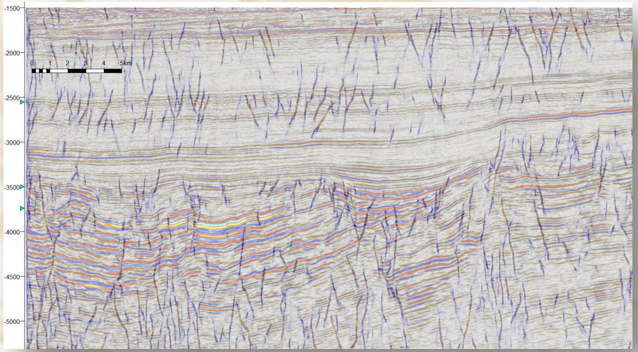
Company C



Company B



Inhouse CoP



FORCE

Why are good open datasets key in further developing ML?

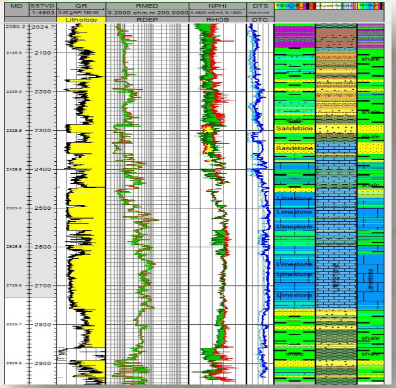
- Open, high-quality data is hard to come by in geoscience
- It provides a common benchmark for vendors and prototypes
- Democratizes ML on subsurface data - students, independents can test ideas and compete on equal footing with companies
- **Openness fosters openness**

All datasets and results are here:

https://github.com/bolgebrygg/Force-2020-Machine-Learning-competition
https://zenodo.org/record/4351156#.YCE1aejAQuU

FORCE

What have we learned, and what would we do different?



- Scoring should be consistent with a petrophysicist’s evaluation
  - Geological scoring matrix improvement
  - Address class imbalance in scoring
  - Consider thin bed scoring that makes an impact

- The true legacy is the dataset
  - Invest in a large, high-quality dataset
  - Keep it raw and realistic
  - Remember that interpreted data is subjective
  - Secure broad funding and collaboration

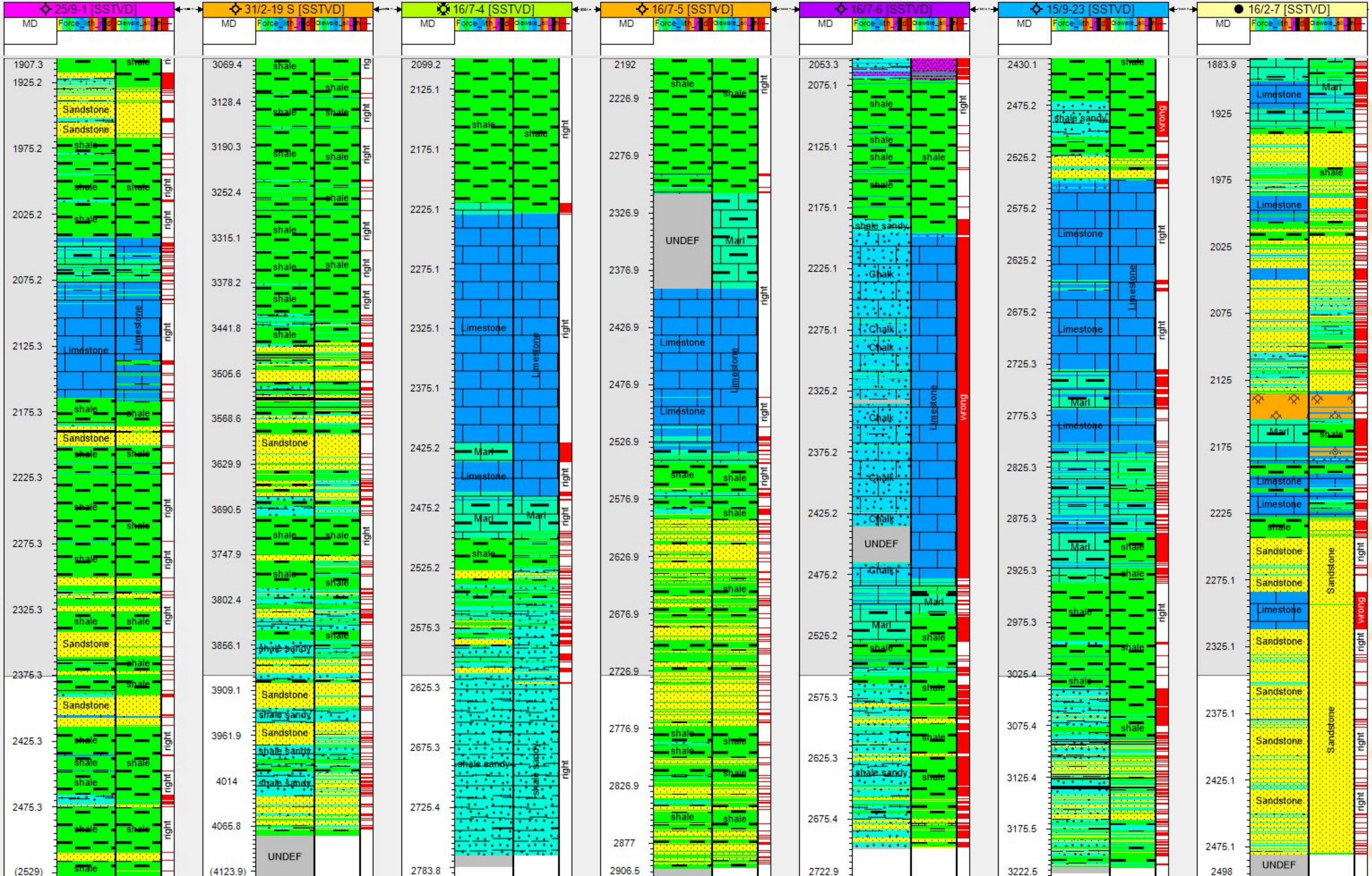
- Keep prizes largely symbolic

- Fault competition was a bust, need to reevaluate its purpose

FORCE

Questions?

Norsk olje&gass
ConocoPhillips
equinor
Woodside
AkerBP
Lloyd's Register
EXPLOCROWD
wintershall dea
Schlumberger
XEEK
i2G™
Agile*



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MD
1907.3 1925.2 1975.2 2025.2 2075.2 2125.3 2175.3 2225.3 2275.3 2325.3 2376.3 2425.3 2475.3 (2529)
3069.4 3128.4 3190.3 3252.4 3315.1 3378.2 3441.8 3505.6 3568.6 3629.9 3690.5 3747.9 3802.4 3856.1 3909.1 3961.9 4014 4065.8 (4123.9)
2099.2 2125.1 2175.1 2225.1 2275.1 2325.1 2375.1 2425.2 2475.2 2525.2 2575.3 2625.3 2675.3 2725.4 2783.8
2192 2226.9 2276.9 2326.9 2376.9 2426.9 2476.9 2526.9 2576.9 2626.9 2676.9 2726.9 2776.9 2826.9 2877 2906.5
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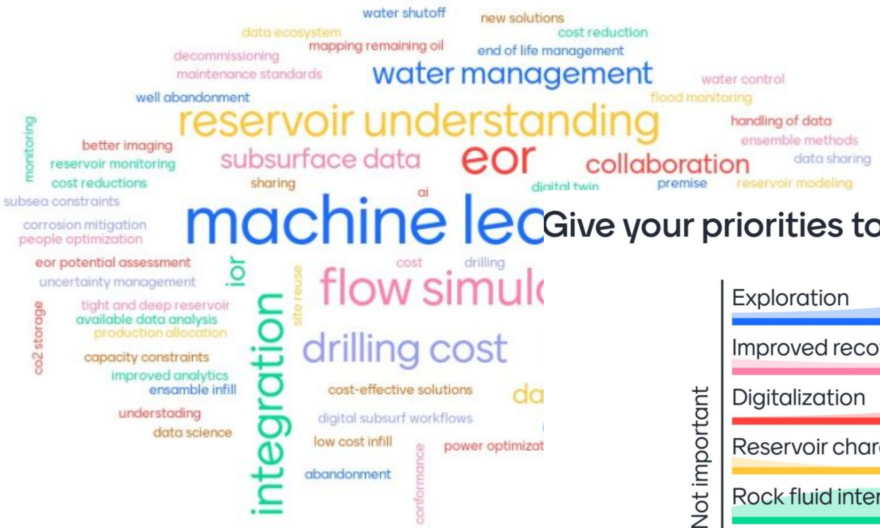
1883.9 1925 1975 2025 2075 2125 2175 2225 2275.1 2325.1 2375.1 2425.1 2475.1 2498

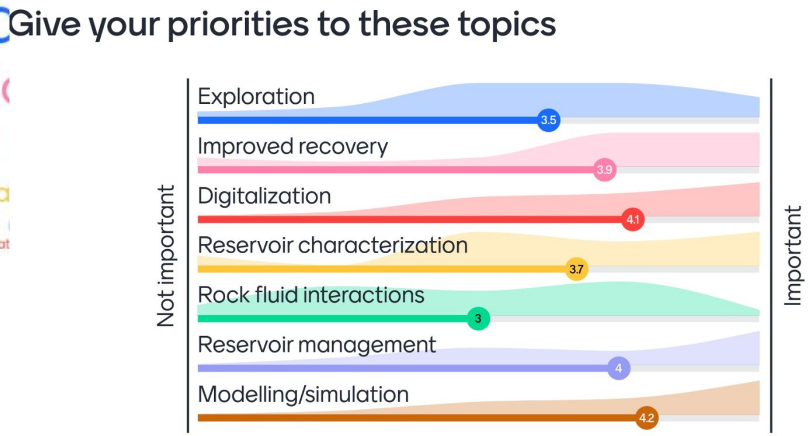
What are the important technology gaps and knowledge needs in exploration of new areas?

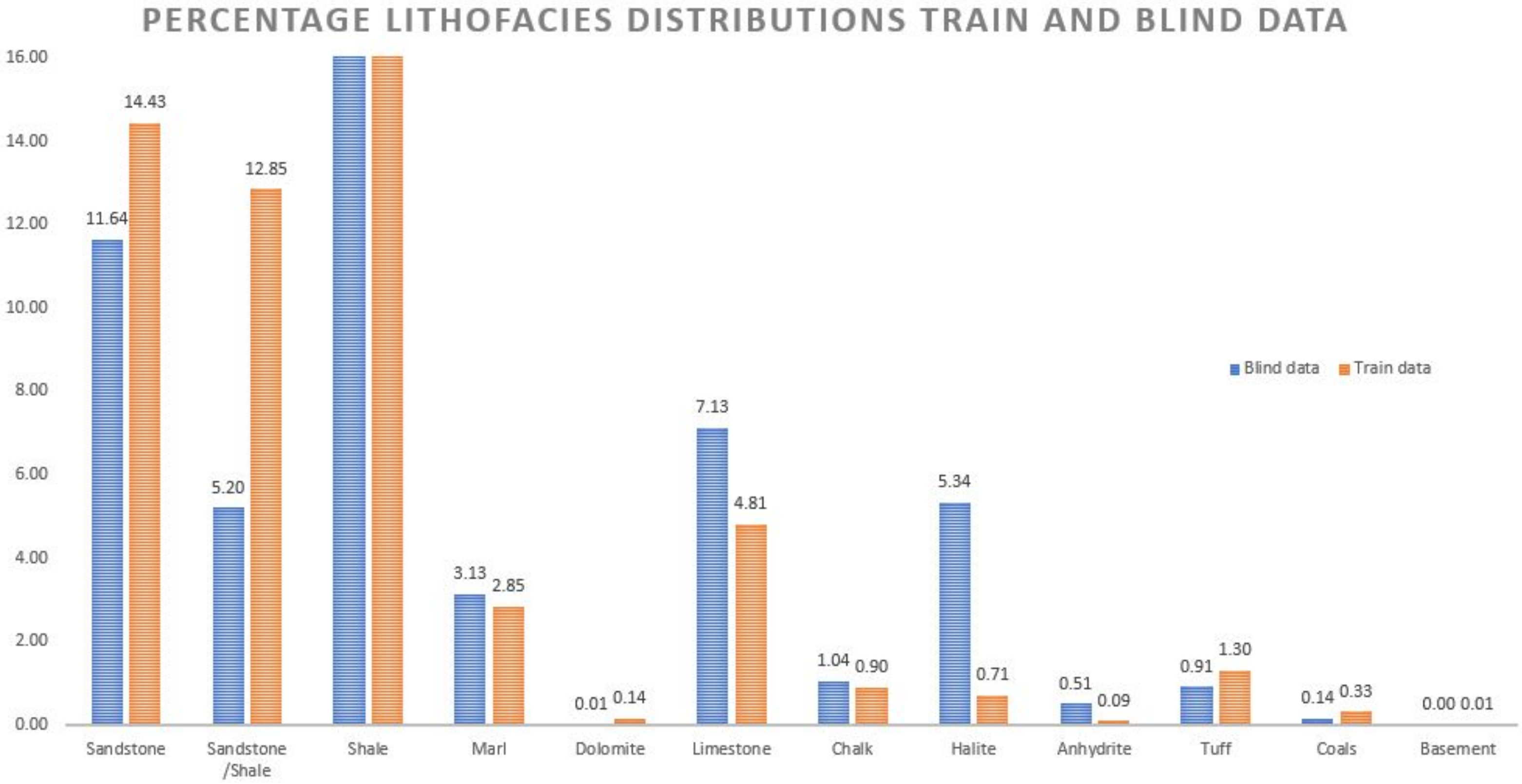
Mentimeter

What are the important technology gaps and knowledge needs in development of mature fields?

Mentimeter






PERCENTAGE LITHOFACIES DISTRIBUTIONS TRAIN AND BLIND DATA
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12.00
10.00
8.00
6.00
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Blind data
Train data
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14.43
5.20
12.85
3.13
2.85
0.01
0.14
7.13
4.81
1.04
0.90
5.34
0.71
0.51
0.09
0.91
1.30
0.14
0.33
0.00
0.01
Sandstone
Sandstone /Shale
Shale
Marl
Dolomite
Limestone
Chalk
Halite
Anhydrite
Tuff
Coals
Basement