Challenges and Solution to AI Application in E&P Decision-Making*

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Abstract

E&P companies strive to organize data, information and knowledge consistently to facilitate comparison, to learn lessons from the past and to better plan for the future. However, the lessons from past investments are seldom fully known or used due to lack of knowledge standards, changes in personnel, strategic priorities, cost controls and simply pressure on time. Artificial Intelligence (AI) including machine learning could be applied readily in many stages of E&P lifecycle. However, machine learning algorithms are best applied to structured and regularized data to gain meaningful results. Data preparation, regularization and standardization represent 90% of the efforts in many AI applications. To analyze and solve more complex subsurface problems at asset or portfolio level using AI, a large amount of effort would have to be made to standardize field and reservoir knowledge. We have conducted in-depth analysis and systematic documentation of the world's most important fields and reservoirs and have established a comprehensive knowledge classification system to regularize reservoir knowledge for decision-making using AI tools. The regularized reservoir knowledge covers every known type of reservoir in all types of petroliferous basin around the world. Each documented field report details how the field was discovered followed by basin genesis and source rock, structure and trap definition, reservoir characteristics and fluid properties all the way to resources and recovery insights, including development strategy, reservoir management and improved recovery techniques applied and their outcomes. A comprehensive knowledge model, with 450 geological and reservoir engineering attributes, has been established at both reservoir and field level. Each attribute has been consistently defined and contains a set of standardized values following a pioneering classification system. Rigorous standards, consistent rules and clear guidelines have been applied to capture reservoir and field knowledge to form a global knowledge base. To facilitate translation of this knowledge base into real-time intelligence and insight, a software platform with a robust search engine and powerful set of analytics has been developed for searching, retrieving, characterizing and benchmarking E&P assets against global analogs. Our industry-leading knowledge base provides a solid foundation for the application of AI and machine learning technologies to optimize the E&P decision-making.

CHALLENGES AND SOLUTION TO AI APPLICATION IN E&P DECISION-MAKING

Presented by

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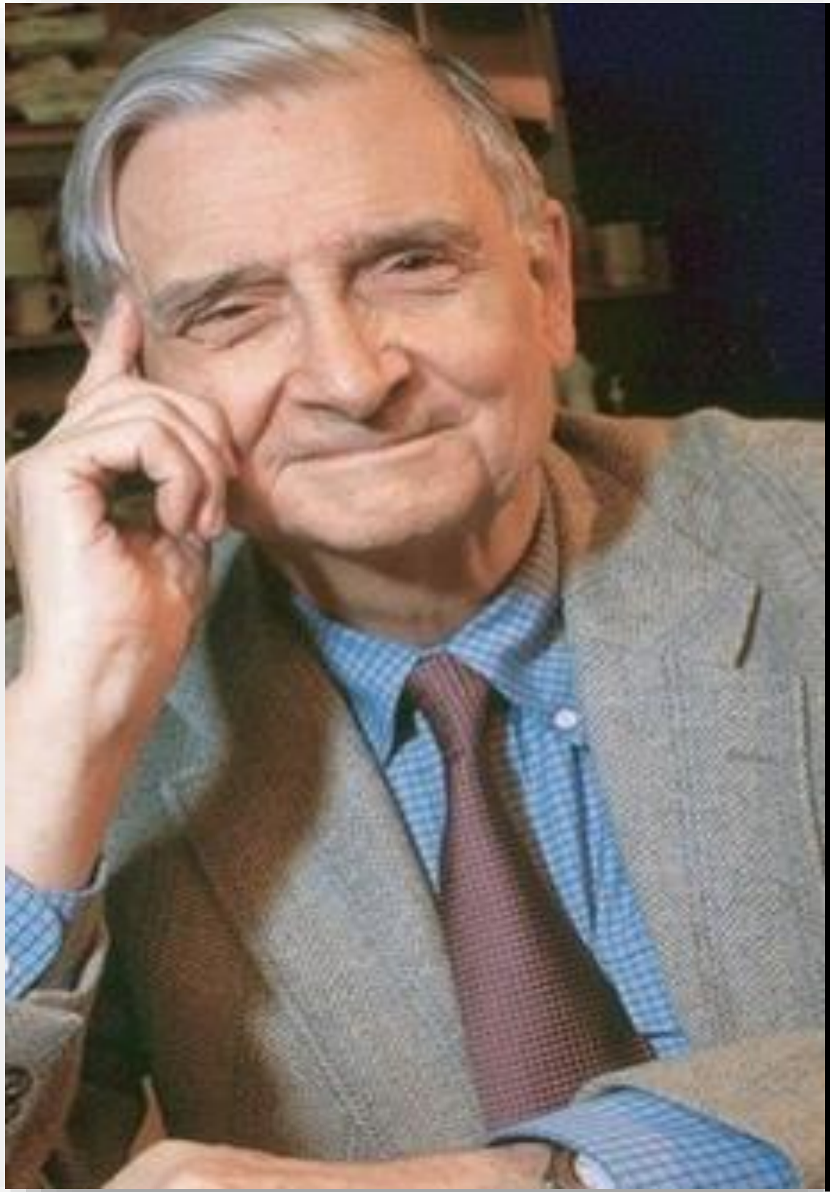
C&C Reservoirs

The intelligence behind the world's most successful oil and gas companies

E&P BUSINESS – WHAT ARE WE COMPETING?



"We are **drowning in information, while starving for wisdom**.
The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely."

Edward O. Wilson - American biologist, researcher, author

ESSENCE OF E&P BUSINESS

- E&P is a knowledge-based business where superior performance is achieved through early identification and appraisal of opportunities and their efficient exploitation
- E&P decisions are subjectively analog-based, pooling companies' collective experience. However, many E&P teams follow an informal and inefficient process that spans only the knowledge gained from the team's own experiences
- Analogs provide the opportunity to learn from local and global experiences and with this additional experience, more insightful and creative ideas can be generated, and better decisions made
- Analogs **(intelligence) + data + technology** = superior performance

CHALLENGE FOR ML& AI APPLICATION

- Machine learning algorithms are best applied to structured and regularized data

- Data preparation, regularization and standardization represents 90% of the efforts in many AI applications

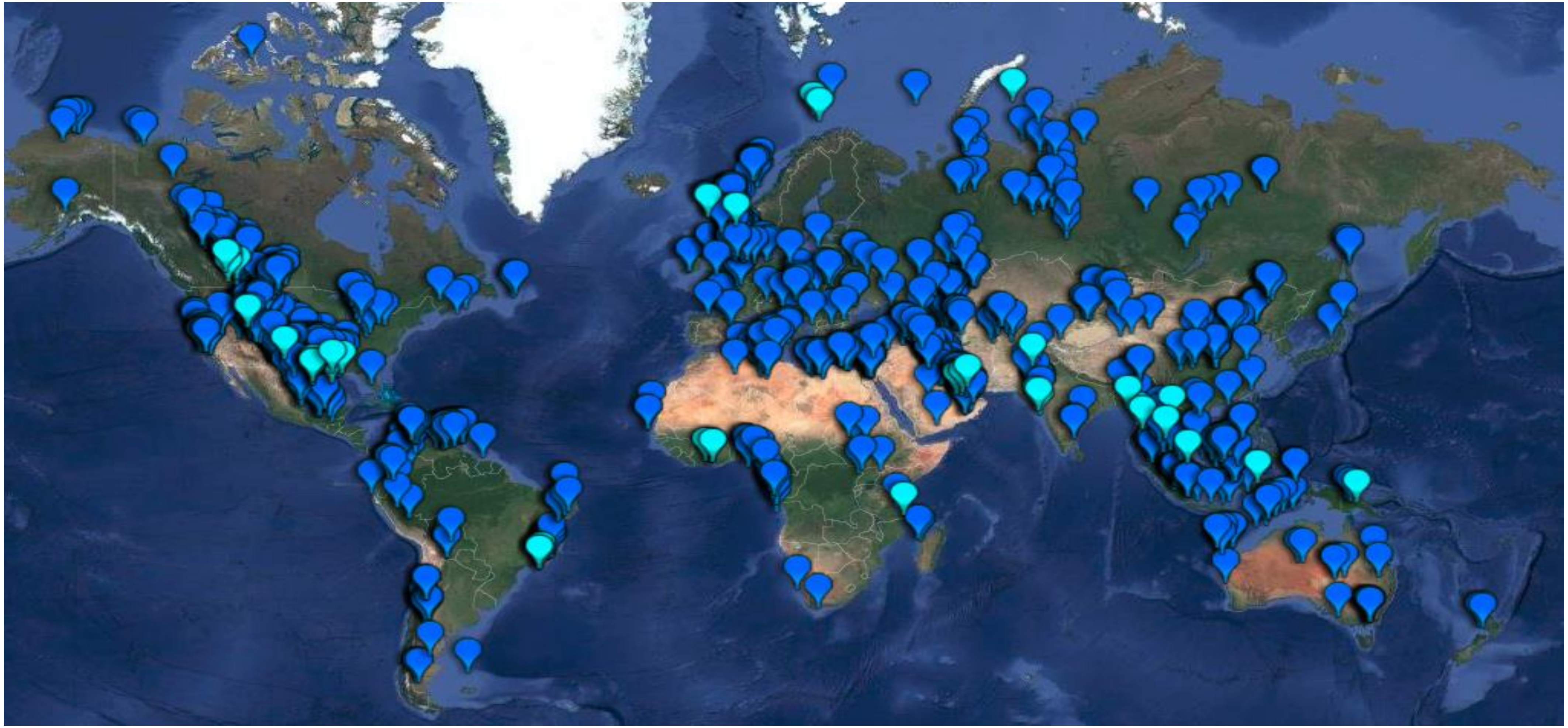
- To analyze and address complicated subsurface issues using AI, a great effort would be required to standardize and classify geological and engineering attributes

OUR SOLUTION TO AI APPLICATION

- Over the past 25 years, we have conducted in-depth analysis and systematic documentation of the world's most important fields and reservoirs
- Established a comprehensive knowledge standard and pioneering classification scheme to regularize field and reservoir knowledge
- Application for AI is phenomenal as it contains a robust data model with >400 geological and engineering attributes
- Each attribute is consistently defined and contains a set of standardized values following a hierarchy of classification
- Rigorous standards, consistent rules and clear guidelines have been applied to capture field and reservoir knowledge and codify them into a coherent knowledge base

GLOBAL FIELD AND RESERVOIR KNOWLEDGE BASE

Every Petroleum Basin, Play/Reservoir Type, Production Technology and Improved Recovery Method around the World



FIELD AND RESERVOIR ANALYSIS

In-depth analysis and systematic documentation of the world's most important fields and reservoirs

- ✓*Exploration history*: play concept & discovery techniques
- ✓*Regional-scale info*: basin evolution & petroleum system
- ✓*Field-scale info*: trap, seal, reservoir & fluid properties
- ✓*Resources and recovery*: development strategy, reservoir management & improved recovery methods
- ✓*Table of parameters (> 400 geological & engineering parameters)*
- ✓*Figure*: map, cross-section, log, plot and production history

KNOWLEDGE STRUCTURE

Reservoir information (330 parameters)

- General
- Well
- Source rock
- Trap
- Seal
- Reservoir characteristics (56)
- Fluid properties
- Resources
- Improved recovery

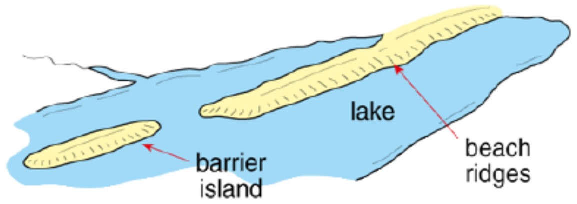
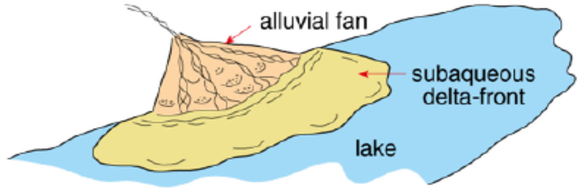
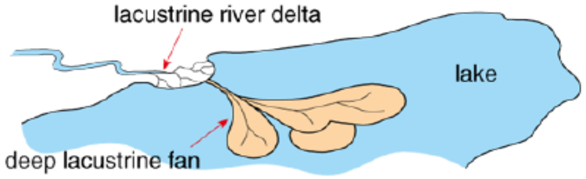
Reservoir production (40 parameters)

Field information (58 parameters)

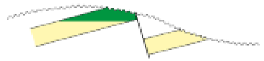
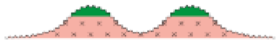
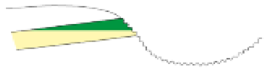
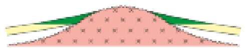
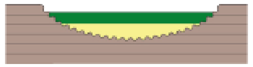
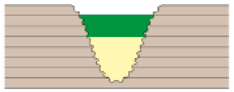
Example Parameter

- Reservoir age
- Depositional environment
- Sand body type
- Fluid flow restriction
- Gross reservoir thickness
- Net reservoir thickness
- Net to gross ratio
- Net pay thickness
- Reservoir lithology
- Wettability/sensitivity
- Formation damage
- Unconventional reservoir type
- Diagenetic reservoir type
- Porosity type
- Matrix/fracture porosity
- Air/well test permeability
- Inter-layer permeability contrast
- Kv/Kh ratio

PIONEERING CLASSIFICATION: LACUSTRINE ENVIRONMENT

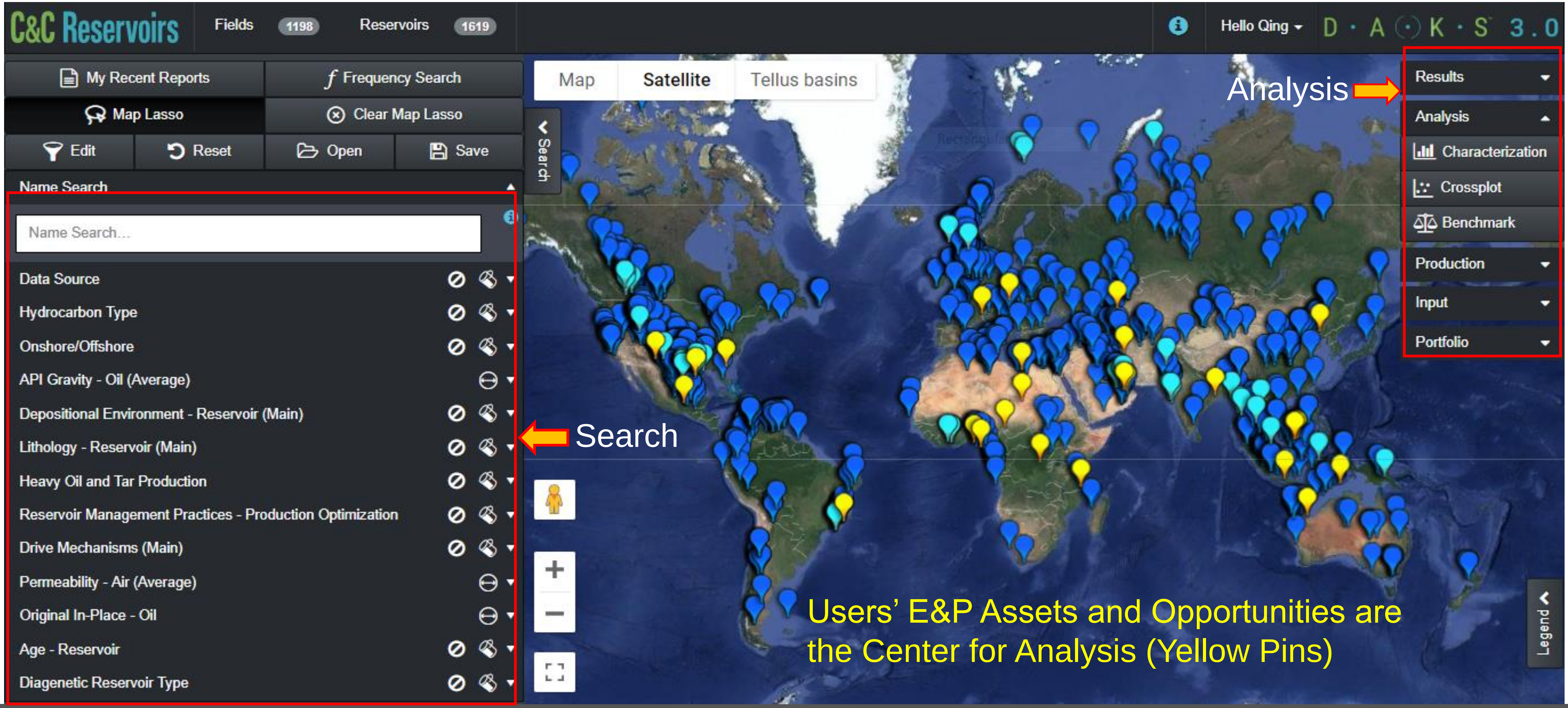
CLASTICS				
DEPOSITIONAL SYSTEM	DEPOSITIONAL ENVIRONMENT		DEFINITION	CONCEPTUAL MODEL
Lacustrine Deposits of non-marine standing bodies of water.	Lacustrine beach or barrier bar		Lake-margin facies formed by reworking by wave action or longshore currents. Typically elongate reservoirs, paralleling the lake shore.	
	Lacustrine delta Sediment prisms deposited at mouths of rivers and alluvial fans.	Lacustrine river-delta	Deposited at river mouths within low-relief distributary systems. Dominated by fluvial processes and interaction with lacustrine wave/longshore currents.	
		Lacustrine fan-delta	Coastal prisms delivered to lake margin by alluvial fans and deposited mainly in shallow water. Developed in high relief basins, typically in semi-arid areas.	
	Sub-lacustrine fan		Turbidites typically deposited downslope of lacustrine river-deltas and pass laterally into deep-lacustrine shales.	

PIONEERING CLASSIFICATION: EROSIONAL TRUNCATION

STRATIGRAPHIC - FLUIDIC				
Erosional Trapping resulting from erosional truncation of reservoir.	Sub-unconformity truncation Reservoir truncation beneath a regional unconformity.	Regional subcrop	Reservoir truncation beneath regional-scale unconformity.	
		Paleostructural subcrop	Erosional truncation of faulted / folded structure.	
	Buried erosional relief Trapping beneath a local truncation surface and/or within a buried hill reservoir.	Buried-hill	Erosional truncation of basement reservoir.	
		Truncation-Edge	Reservoir truncation beneath local / subregional unconformity or sequence boundary.	
	Onlap onto erosional surface Onlap pinch-out of reservoir onto relative high.	Onlap onto regional unconformity	Onlap pinch-out onto a regional unconformity.	
		Onlap onto structural flank unconformity	Onlap pinch-out onto flanks of structural / basement high.	
	Erosional trough fill Lateral termination of reservoir against an erosional trough.	Channel-fill	Reservoir confined within a channel incision..	
		Valley-fill	Reservoir confined within a major channel incision.	
		Canyon-fill	Reservoir confined within deepwater submarine erosional trough.	

DIGITAL ANALOG KNOWLEDGE SYSTEM (DAKS)

DAKS provides an asset-centered, knowledge-based platform for E&P decision-making by leveraging Collective Human Intelligence



COLLECTIVE HUMAN INTELLIGENCE

Integration of users' expertise, knowledge on their E&P assets and insights from the world's most important fields and reservoirs

- Key facts, best practices and lessons learned
- Intelligence of the companies behind those important fields and reservoirs
- Knowledge capture on users' E&P assets
- Benchmarking of users' assets against global 'best practices'
- Discovery of critical issues and identification of new opportunities for improvement

KNOWLEDGE CAPTURE: ZAMA DISCOVERY

Field parameters

Reservoir parameters

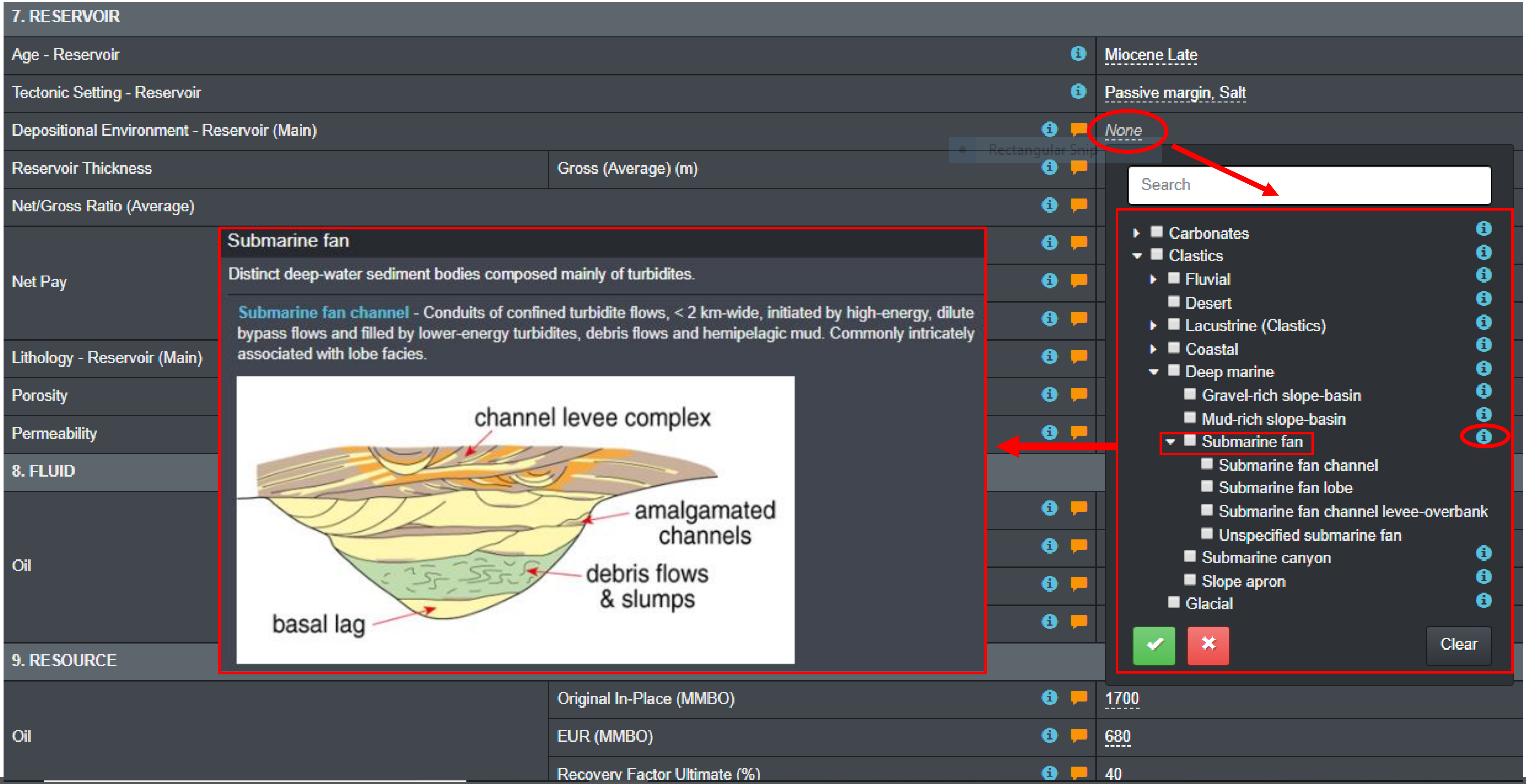
- ❖ General, well, source, trap, seal, reservoir, fluid, resource, improved recovery
- ❖ Bulk data import

Zama Discovery	18.398579	-94.206989	Latin America	Mexico		Salinas - Sureste	Offshore	Edit	Delete

Create New Reservoir

Reservoir Unit Name	Hydrocarbon Type		
Zama sst	Oil only	Edit	Delete

CLASSIFICATION: ZAMA DEPOSITIONAL ENVIRONMENT



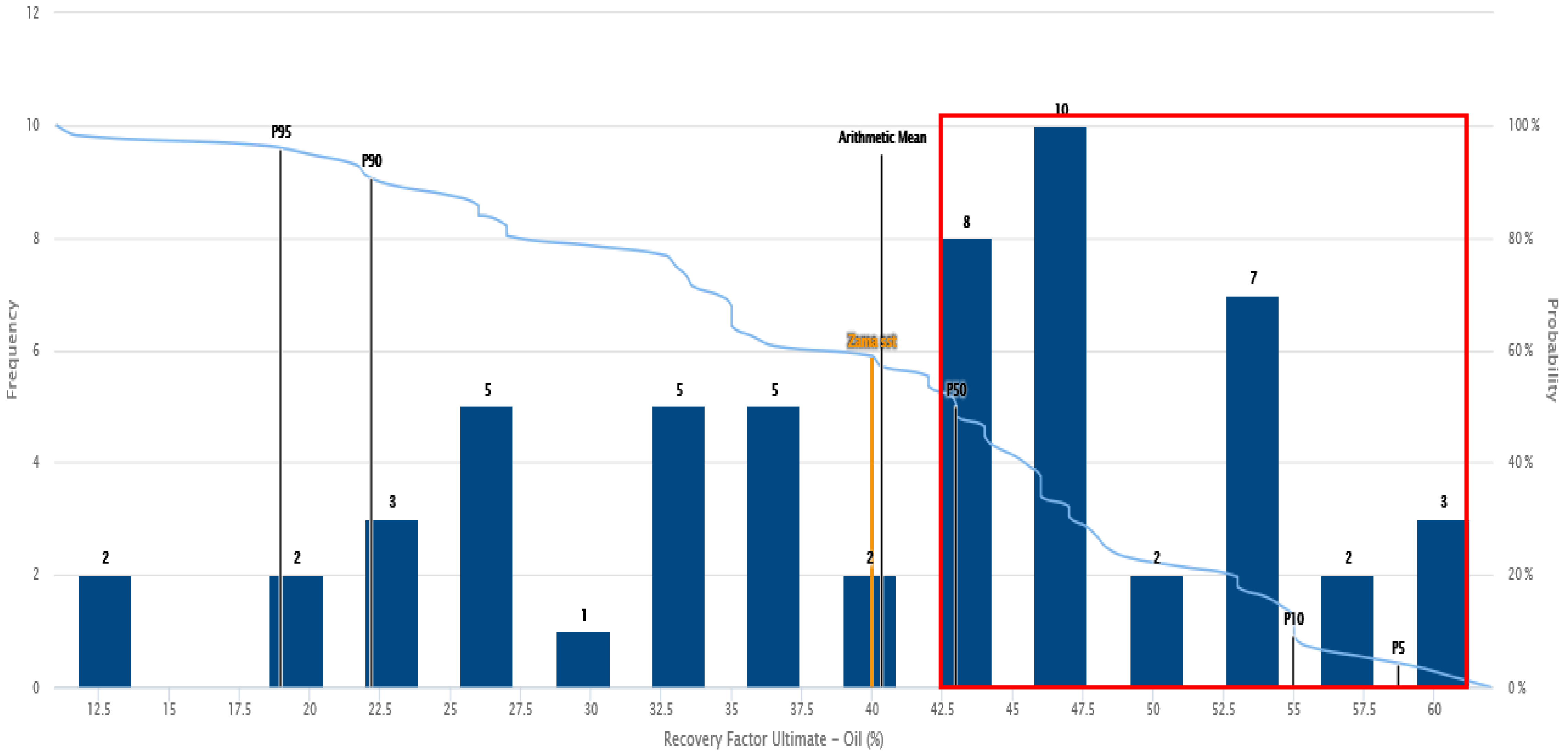
KNOWLEDGE CAPTURE: ZAMA DISCOVERY

7. RESERVOIR		
Age - Reservoir		Miocene Late
Tectonic Setting - Reservoir		Passive margin, Salt
Depositional Environment - Reservoir (Main)		Submarine fan
Reservoir Thickness	Gross (Average) (m)	510.84
Net/Gross Ratio (Average)		0.7
Net Pay	Average (m)	185.01
	Minimum (m)	170.08
	Maximum (m)	202.69
Lithology - Reservoir (Main)		Sandstone
Porosity	Matrix (Average) (%)	25
Permeability	Air (Average) (mD)	450
8. FLUID		
Oil	API Gravity (Average) (°API)	29
	API Gravity (Minimum) (°API)	28
	API Gravity (Maximum) (°API)	30
	GOR Initial (Average) (SCF/STB)	450
9. RESOURCE		
Oil	Original In-Place (MMBO)	1700
	EUR (MMBO)	680
	Recovery Factor Ultimate (%)	40

BENCHMARK TABLE: NUMERICAL PARAMETERS

Category	Parameter	Units	Count	Benchmark	Rank ↑	Mean	Min	P90	P50	P10	Max
Trap	Productive Area (Original)	ac	21	3200	90 %	23,534	1200	2780	12,700	39,489	160,550
Field	Water Depth (Field)	ft	23	546	73 %	2607.8	125	158.4	2800	5769	7816.99
Reservoir	Permeability - Air (Average)	mD	22	450	67 %	1159.18	71	249	770	2660	6000
Field	Original In-Place - Oil (Field)	MMBO	23	1700	64 %	2848.83	521	748	2100	5278.35	11,400
Reservoir	Porosity - Matrix (Average)	%	22	25	62 %	25.99	18	20.49	26	30.6	33
Field	EUR - Oil (Field)	MMBO	21	680	60 %	1098.56	145	306.86	800	2860	3107.17
Fluid	GOR Initial (Average)	SCF/STB	23	450	55 %	631.03	82.5	232.5	555	1255.2	1875
Resource	Original In-Place - Oil	MMBO	23	1700	50 %	2453.41	521	710.24	1700	5278.35	11,400
Fluid	API Gravity - Oil (Average)	°API	23	29	45 %	29.75	20	21.8	28	40	46
Field	Recovery Factor - Oil (Field)	%	21	40	45 %	37.9	17.8	25	35.26	53.13	62.6
Resource	Recovery Factor Ultimate - Oil	%	21	40	45 %	38.53	20.2	25	35.72	57.28	62
Resource	EUR - Oil	MMBO	21	680	45 %	994.27	145	246.76	676	2860	3107.17
Reservoir	Net/Gross Ratio (Average)		15	0.7	43 %	0.66	0.38	0.44	0.7	0.85	0.86
Field	Plateau Recovery Annual % of In-Place - Oil (Field)	%	18	3.76	24 %	3.11	1.65	1.72	2.9	4.77	6.8
Reservoir	Reservoir Thickness - Gross (Average)	ft	14	1676	15 %	894.26	83	89.5	805	2015	2150
Trap	Depth to Top of Reservoir	ft TVDML	23	11,000	9 %	6448.32	1835	3642.4	5733	11,372	14,920
Trap	Hydrocarbon Column Height (Original) - Total	ft	19	3018	6 %	1251.42	279	465.8	900	3010.8	3700

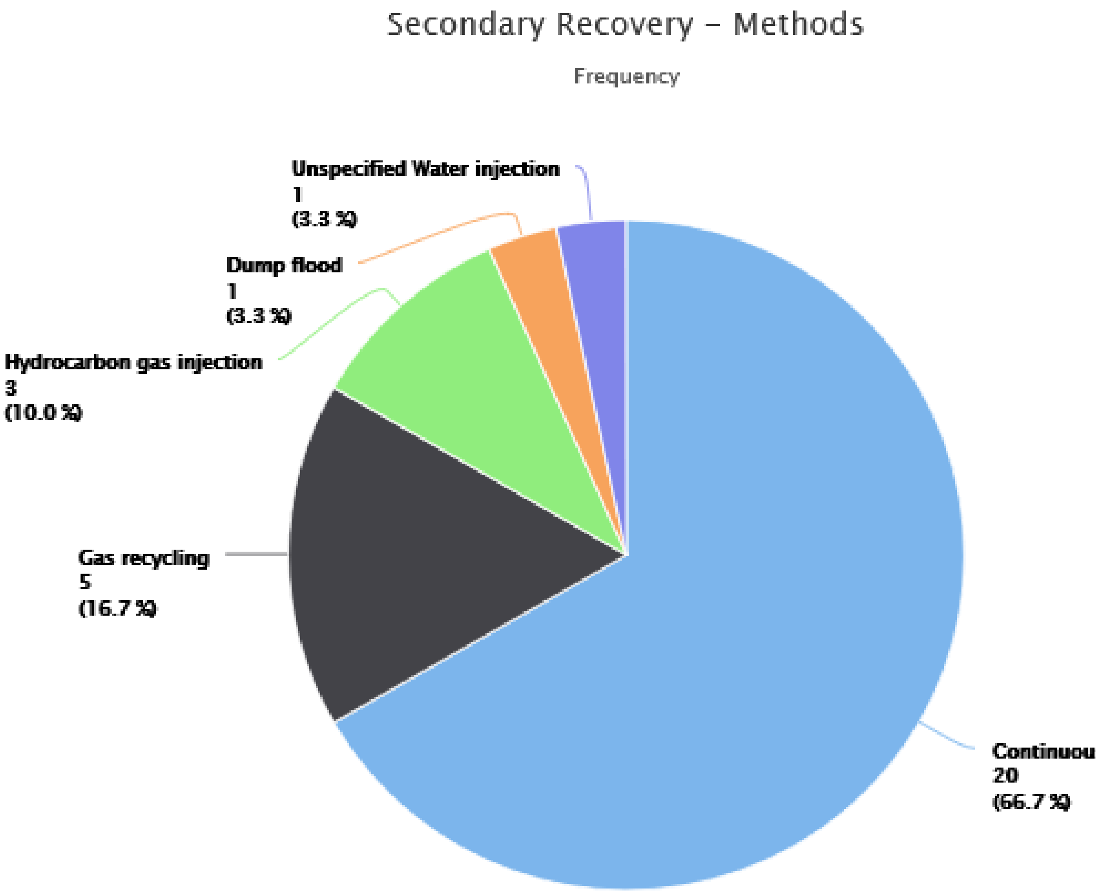
BENCHMARKING RECOVERY FACTOR

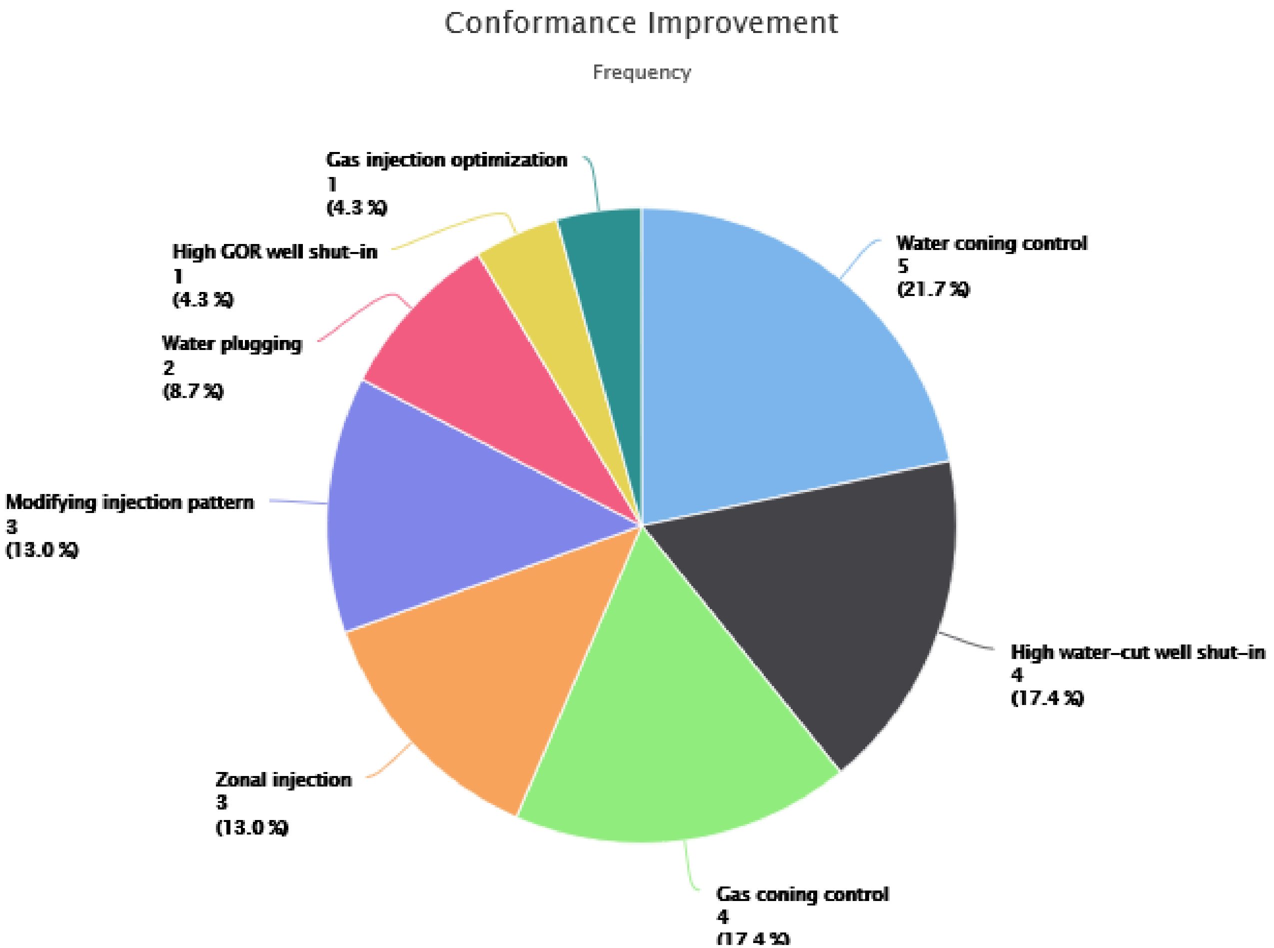


RESERVOIR MANAGEMENT BEST PRACTICES

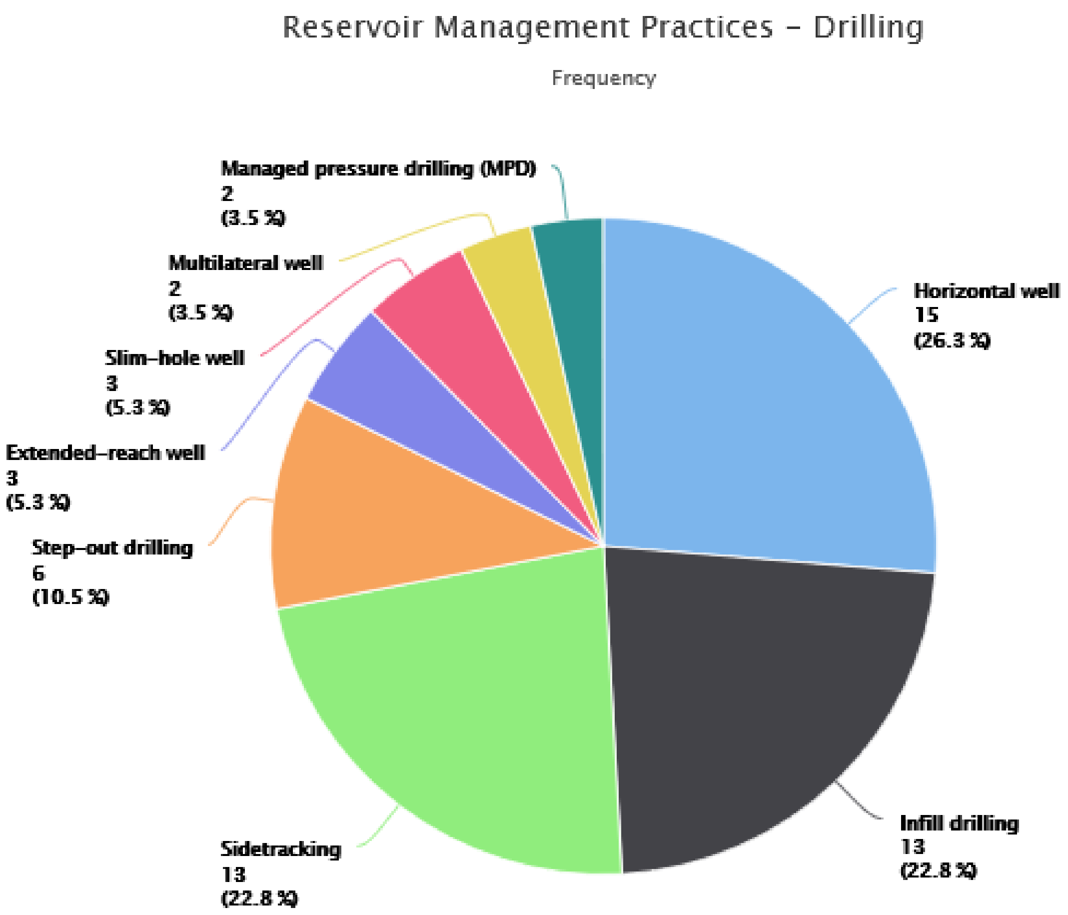
Category	Parameter	Count	First	Second	Third	Fourth	Fifth
Improved Recovery	Techniques to Characterize Remaining Hydrocarbons	25	Reservoir simulation (22 %)	4-D time-lapse seismic (22 %)	Production logging tool (PLT) (14 %)	Core analysis (12 %)	G&G and performance data analysis (9 %)
Improved Recovery	Secondary Recovery - Methods	24	Continuous water injection (67 %)	Gas recycling (17 %)	Hydrocarbon gas injection (10 %)	Dump flood (3 %)	Unspecified Water injection (3 %)
Improved Recovery	Secondary Recovery - Scale: Pilot	1	Dump flood (100 %)				
Improved Recovery	Secondary Recovery - Scale: Partial Application	3	Continuous water injection (75 %)	Gas recycling (25 %)			
Improved Recovery	Secondary Recovery - Scale: Fieldwide Application	16	Continuous water injection (65 %)	Gas recycling (20 %)	Hydrocarbon gas injection (15 %)		
Improved Recovery	EOR - Methods	1	Hydrocarbon miscible flood (100 %)				
Improved Recovery	Conformance Improvement	12	Water coning control (22 %)	High water-cut well shut-in (17 %)	Gas coning control (17 %)	Zonal injection (13 %)	Modifying injection pattern (13 %)
Improved Recovery	Reservoir Management Practices - Drilling	26	Horizontal well (26 %)	Infill drilling (23 %)	Sidetracking (23 %)	Step-out drilling (11 %)	Extended-reach well (5 %)
Improved Recovery	Reservoir Management Practices - Completion	18	Barefoot completion (20 %)	Perforated casing (20 %)	Perforated liner (17 %)	Dual completion (11 %)	Intelligent completion (9 %)
Improved Recovery	Reservoir Management Practices - Perforation	8	Tubing-conveyed perforation (TCP) (33 %)	Wireline-conveyed perforation (20 %)	Underbalanced perforation (20 %)	Through-tubing perforation (TTP) (13 %)	Overbalanced perforation (7 %)
Improved Recovery	Reservoir Management Practices - Sand Control	15	Cased-hole gravel pack (31 %)	Stand-alone sand screen (19 %)	Frac-pack (16 %)	Open-hole gravel pack (9 %)	Pressure drawdown control (6 %)
Improved Recovery	Reservoir Management Practices - Stimulation	10	Matrix acidization (80 %)	Hydraulic fracturing (single-stage) (20 %)			
Improved Recovery	Reservoir Management Practices - Artificial Lift	17	Gas lift (84 %)	Electric submersible pump (ESP) (16 %)			
Improved Recovery	Reservoir Management Practices - Production Optimization	10	Recompletion (44 %)	Re-perforation (19 %)	Gas-cap blowdown (13 %)	Drilling and completion fluid optimization (6 %)	Additional perforation (6 %)
Improved Recovery	Reservoir Management Practices - Well Treatment	7	Scale inhibitor treatment (27 %)	Corrosion inhibitor treatment (18 %)	Hydrate inhibitor treatment (18 %)	Wax removal (18 %)	Sand cleaning (9 %)

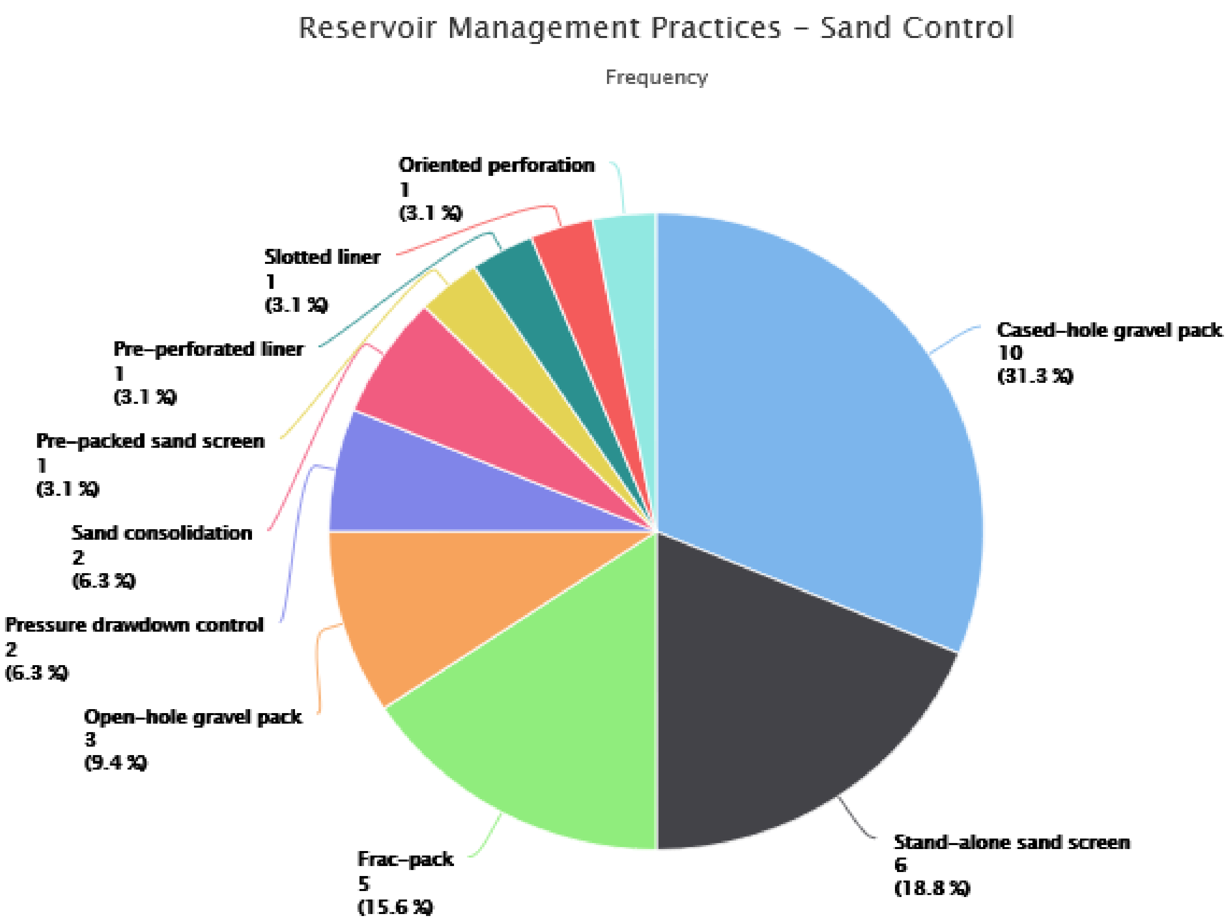
SECONDARY RECOVERY AND CONFORMANCE IMPROVEMENT





RESERVOIR MANAGEMENT BEST PRACTICES

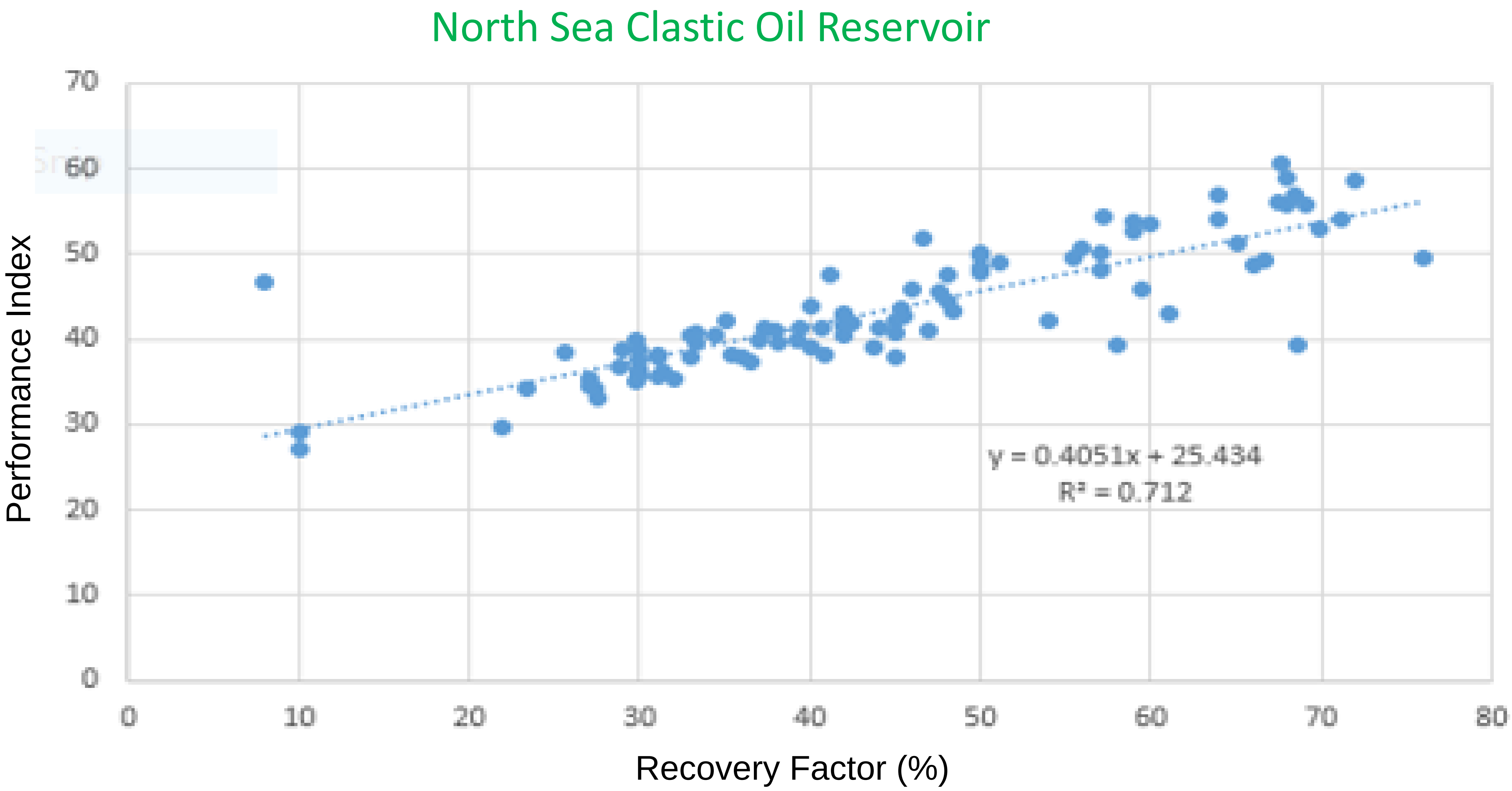




MACHINE LEARNING APPLICATION

- Regularization of subsurface E&P knowledge
- Predictive models for various value drivers: recovery factor for given reservoirs in certain conditions
- Controlling factor analysis: ultimate recovery factor, EUR/well for various reservoirs that were developed using different technologies
- Optimization of various development scenarios

MACHINE LEARNING APPLICATION



CONCLUSION

Digital Transformation is not about technology – it is about change

- In the advent of AI technology, capturing historical and current human knowledge is a fundamental and critical step
- Knowledge standardization requires a robust data model with a well-defined classification scheme and rigorous guidelines/rules
- Our asset-centered, knowledge-based platform facilitates integration and transformation of various experiences and knowledge into collective human intelligence and allows application of AI and machine learning technology to optimize E&P decision-making