VIETNAM OIL AND GAS GROUP

VIETNAM PETROLEUM INSTITUE

ESTIMATION OF TOTAL ORGANIC CARBON USING ARTIFICIAL INTELLIGENCE TECHNIQUES

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Contents

INTRODUCTION

- In term of source rock, sedimentary rocks may become or have been able to generate petroleum are source rocks
- Total Organic Carbon (TOC) is one of the most important parameters that measured the quantity but not the quality of organic carbon in sedimentary rocks.
- Total organic carbon or kerogen content is an indicator of potential hydrocarbon source rocks.
- Total organic carbon is needed for calculating original organic carbon (TOC_o) that supported for petroleum system modeling

Therefore, TOC parameter needs to be measured or estimated for source rock evaluation

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APPLICATION OF TOC IN SOURCE ROCK EVALUATION

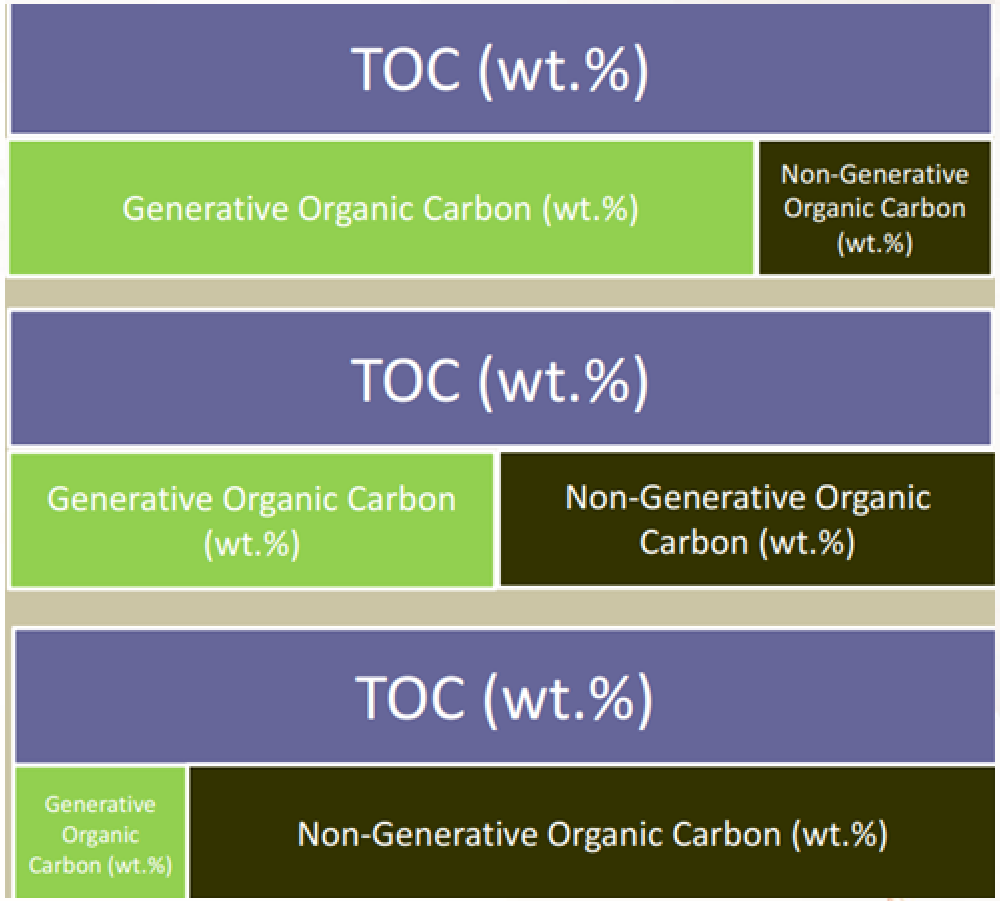
TOTAL ORGANIC CARBON (TOC)

1. Total Organic Carbon (TOC)

TOC refers to the amount of organic carbon in sedimentary rocks, soils or in a geological formation, particularly the source rock for a petroleum play.

TOC parameter is:

- A measure of present-day organic carbon content as received in the laboratory
- It is reported in weight percent but can be converted to volume percent
- It can be restored to original values with knowledge of original kerogen composition
- It will be affected by the presence of organic additives and other conditions



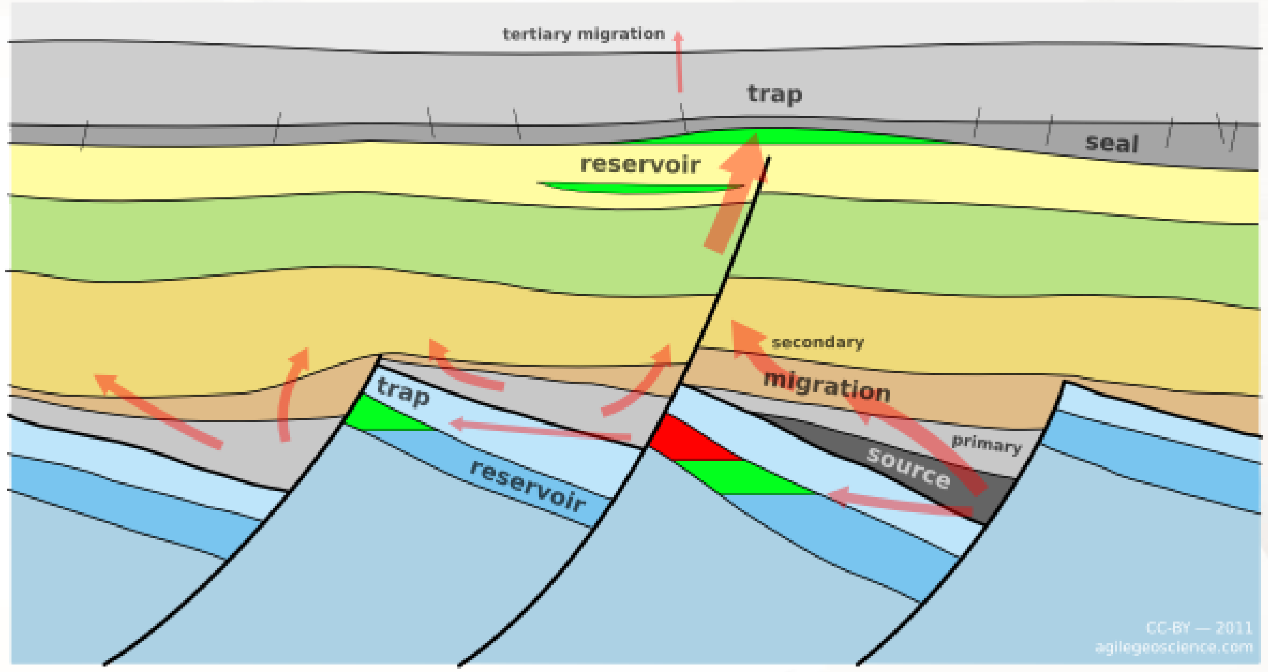
TOTAL ORGANIC CARBON (TOC)

2. Source rock (SR)

In conventional petroleum system

- a rock unit containing sufficient organic matter of suitable chemical composition to generate and expel petroleum;
- the SR must be thermally mature;
- expulsion of hydrocarbons must occur from that SR;
- a trap for these hydrocarbons must exist somewhere;
- the expelled hydrocarbons must migrate from the source to the trap

Conventional petroleum system

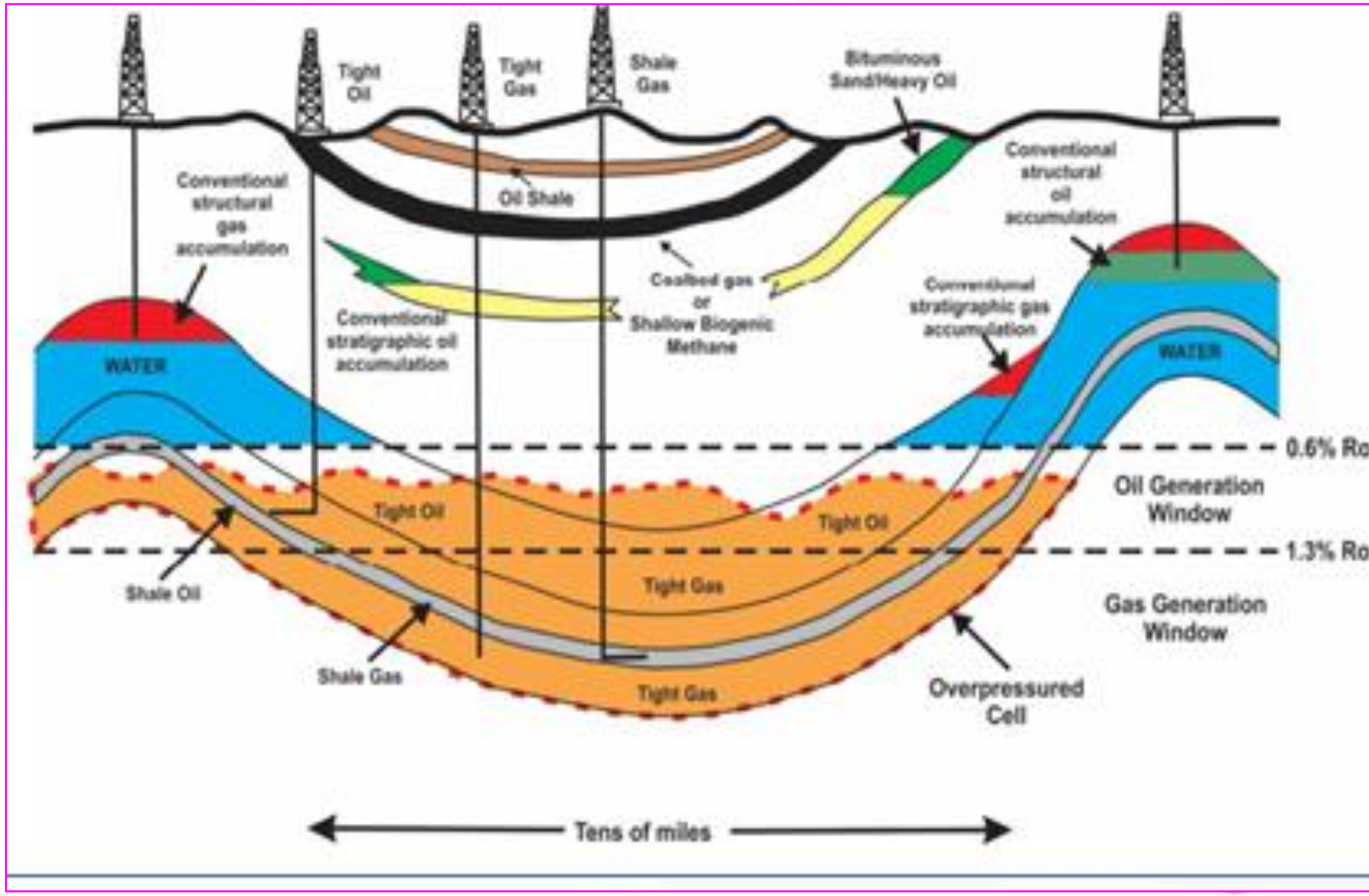


TOTAL ORGANIC CARBON (TOC)

In Tight petroleum system /unconventional reservoir

- Shale SR is recognized as a potential reservoir for hydrocarbons with very low permeability and high content of OM
- In a shale reservoir, gas typically occurs in two modes: adsorbed on OM within the shale bed
- The low permeability of shale reservoirs specifically hydraulic fracturing

Unconventional reservoirs: Coal bed methane (CBM), Shale oil and shale gas, Tight gas sands, Fractured reservoirs, Gas hydrate



TOTAL ORGANIC CARBON (TOC)

3. Application of TOC in source rock evaluation

- Defining current quantity of organic matter;
- Defining original TOC for input data in petroleum system modeling;
- A key factor in determining the prospectivity of any shale play;
- It significantly influences hydrocarbon production

4. Screening source rock evaluation

Source rock assessment is based on parameters, i.e., **TOC**, S1, S2, S3, HI, PI, Tmax, Ro that are traditionally measured on Rock-Eval machine in laboratory from cores, SWCs and cuttings

However, this analysis provides non-continuous measurements of the source rock section as it has limited samples and is usually associated with higher costs and longer measurement time

To overcome these limitations, **Artificial Intelligence** techniques are applied for estimation TOC

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LAB ANALYSIS TECHNIQUES

METHODS OF MEASURING TOC

TOC is determined by analyses:

1. LECO

- Defining TOC
- Often used for sediemtary rocks with high carbonate content

2. ROCK-EVAL

- The pyrolytic analysis is performed on Rock-Eval I/II/6 that is widely used for sedimentary rocks
- Providing TOC and pyrolytic parameters: S1, S2, S3, HI, PI, Tmax

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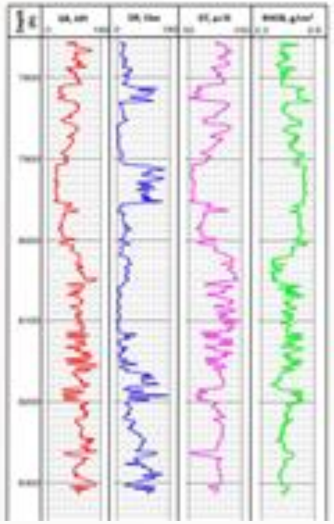
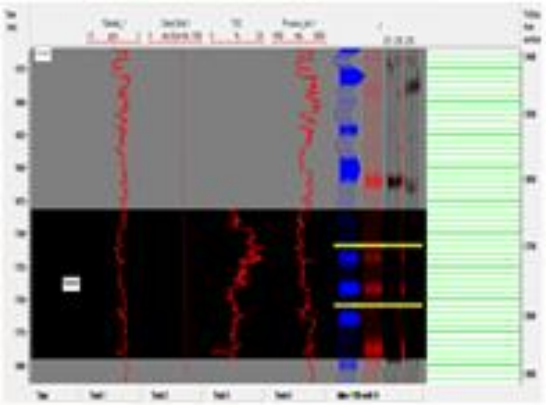
CALCULATION TECHNIQUES

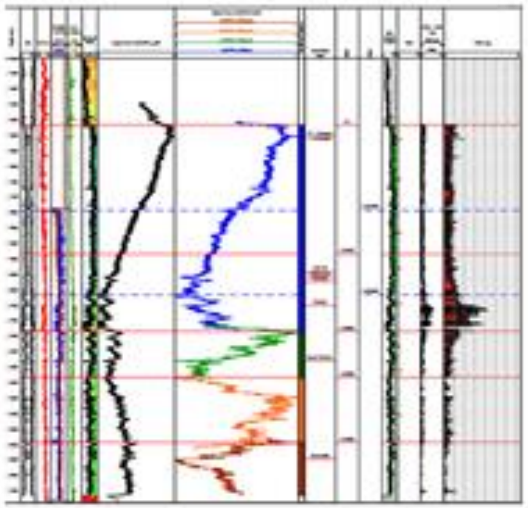
CALCULATION TECHNIQUES

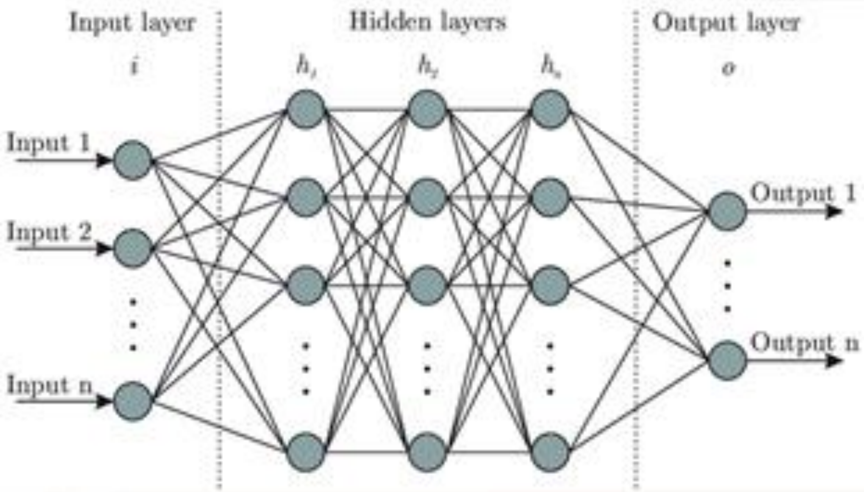
Some techniques are applied for TOC calculation as follows:

- Well logging data
- Seismic section combining with well logs
- Softwares based on well logs: Cyclolog, Interactive Petrophysics, Techlog, etc.
- Artificial Intelligence (AI) models









CALCULATION TECHNIQUES

❖ Calculating TOC from well logs

- Well logging methodology in geochemical evaluation is an important technique not only for its usefulness as a quick scan of potential source rock, but also in its ability to identify the organic richness (TOC, wt.%) of these rocks
- Wireline logs can be used to identify source rock intervals in the primary stage of well drilling
- Consequently, the logs used for source rock evaluations and calculation of Total Organic Carbon (TOC) most commonly include density, sonic, gamma ray, neutron and resistivity using several methods

  In this study, a suite of geophysical logs and measured TOC were applied for determining TOC and compare them together

CALCULATION TECHNIQUES

❖ Calculating TOC from well logs

- The presence of Organic matter (OM) generally associated with: higher GR, lower Density, higher Resistivity, slower Sonic
- TOC can be calculated by overlaying log curves: Resistivity-Sonic, Resisitivity-Neutron, Resistivity-Density (Passey et al., 1990)

$\Delta \log R = \log_{10}(R/R_b) + 0.02 * (\Delta t - \Delta t_b)$

Est. TOC = $(\Delta \log R) * 10^{(2.297-0.1688*LOM)}$

where: $\Delta \log R$ = Log overlay seperation

R = deep resistivity

R_b: baseline resistivity

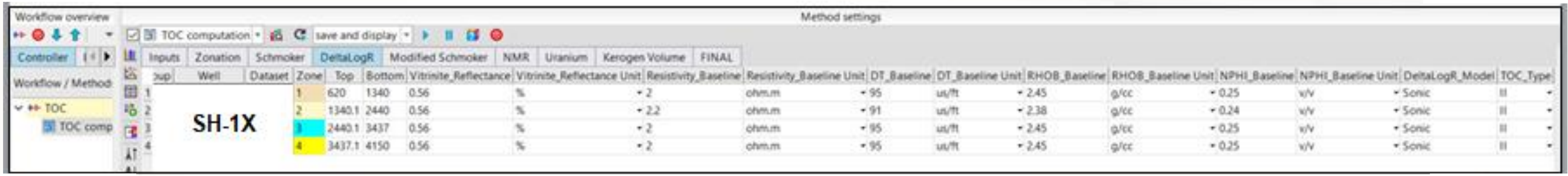
Δt = sonic curve transit time value

Δt_b = sonic curve transit time baseline value

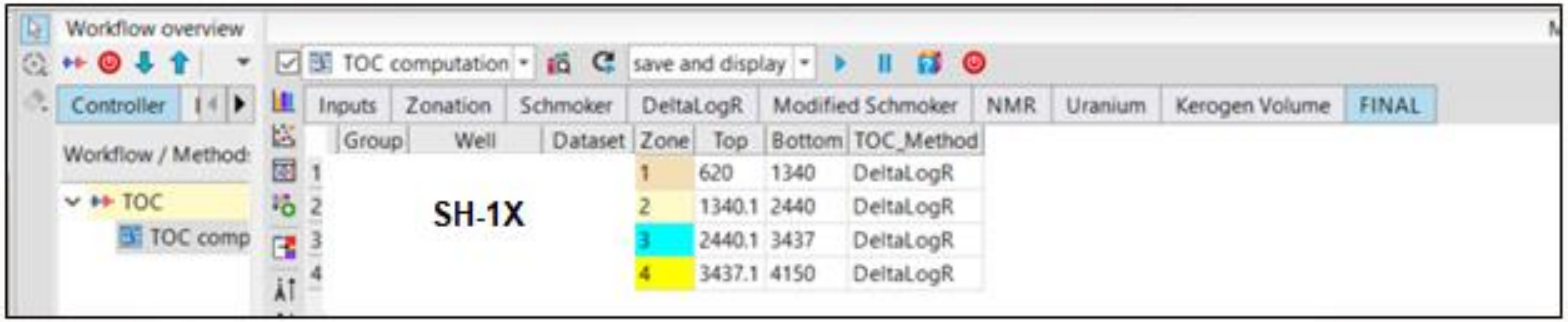
LOM = Level of organic maturity

A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

Workflow of calculating TOC



	Group	Well	Dataset	Zone	Top	Bottom	Vitrinite_Reflectance	Vitrinite_Reflectance Unit	Resistivity_Baseline	Resistivity_Baseline Unit	DT_Baseline	DT_Baseline Unit	RHOB_Baseline	RHOB_Baseline Unit	NPHI_Baseline	NPHI_Baseline Unit	DeltaLogR_Model	TOC_Type
1		SH-1X		1	620	1340	0.56	%	2	ohm.m	95	us/ft	2.45	g/cc	0.25	v/v	Sonic	III
2				2	1340.1	2440	0.56	%	2.2	ohm.m	91	us/ft	2.38	g/cc	0.24	v/v	Sonic	III
3				3	2440.1	3437	0.56	%	2	ohm.m	95	us/ft	2.45	g/cc	0.25	v/v	Sonic	III
4				4	3437.1	4150	0.56	%	2	ohm.m	95	us/ft	2.45	g/cc	0.25	v/v	Sonic	III

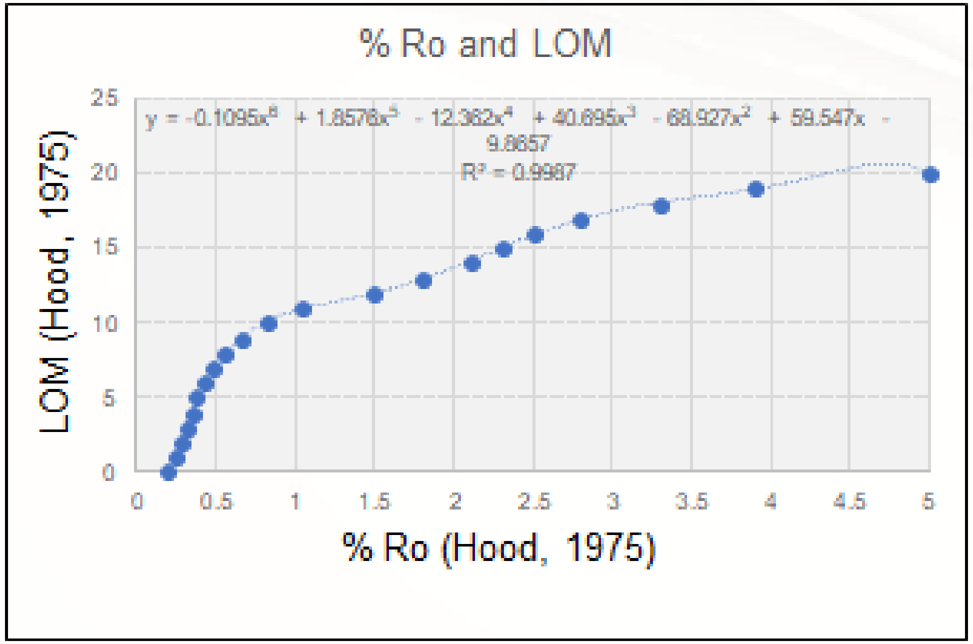


	Group	Well	Dataset	Zone	Top	Bottom	TOC_Method
1		SH-1X		1	620	1340	DeltaLogR
2				2	1340.1	2440	DeltaLogR
3				3	2440.1	3437	DeltaLogR
4				4	3437.1	4150	DeltaLogR

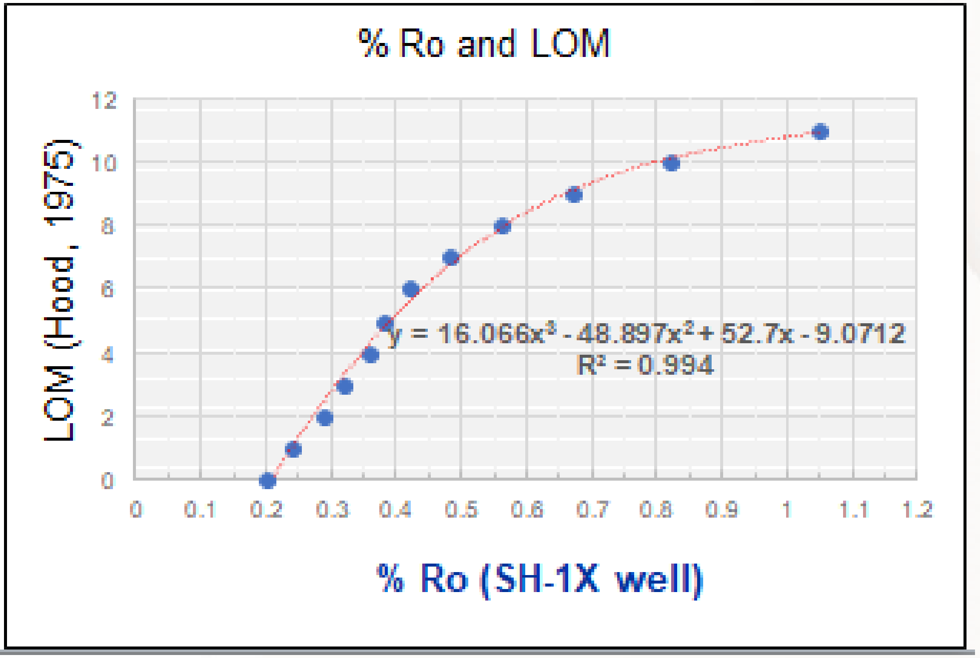
A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

Respective maturity in LOM unit Metamorphism

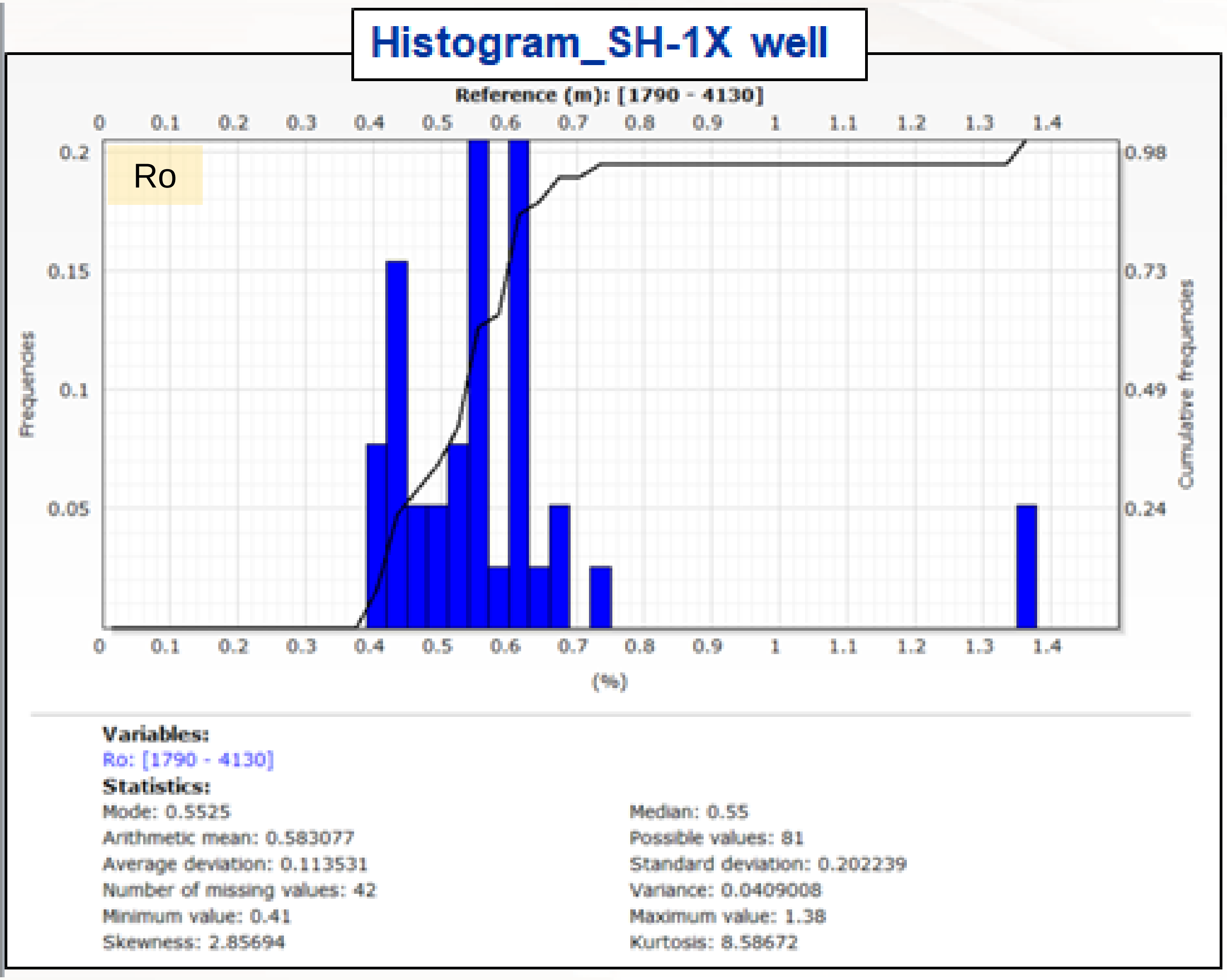
LOM	Ro
0	0.2
1	0.24
2	0.29
3	0.32
4	0.36
5	0.38
6	0.42
7	0.48
8	0.56
9	0.67
10	0.82
11	1.05
12	1.5
13	1.8
14	2.1
15	2.3
16	2.5
17	2.8
18	3.3
19	3.9
20	5

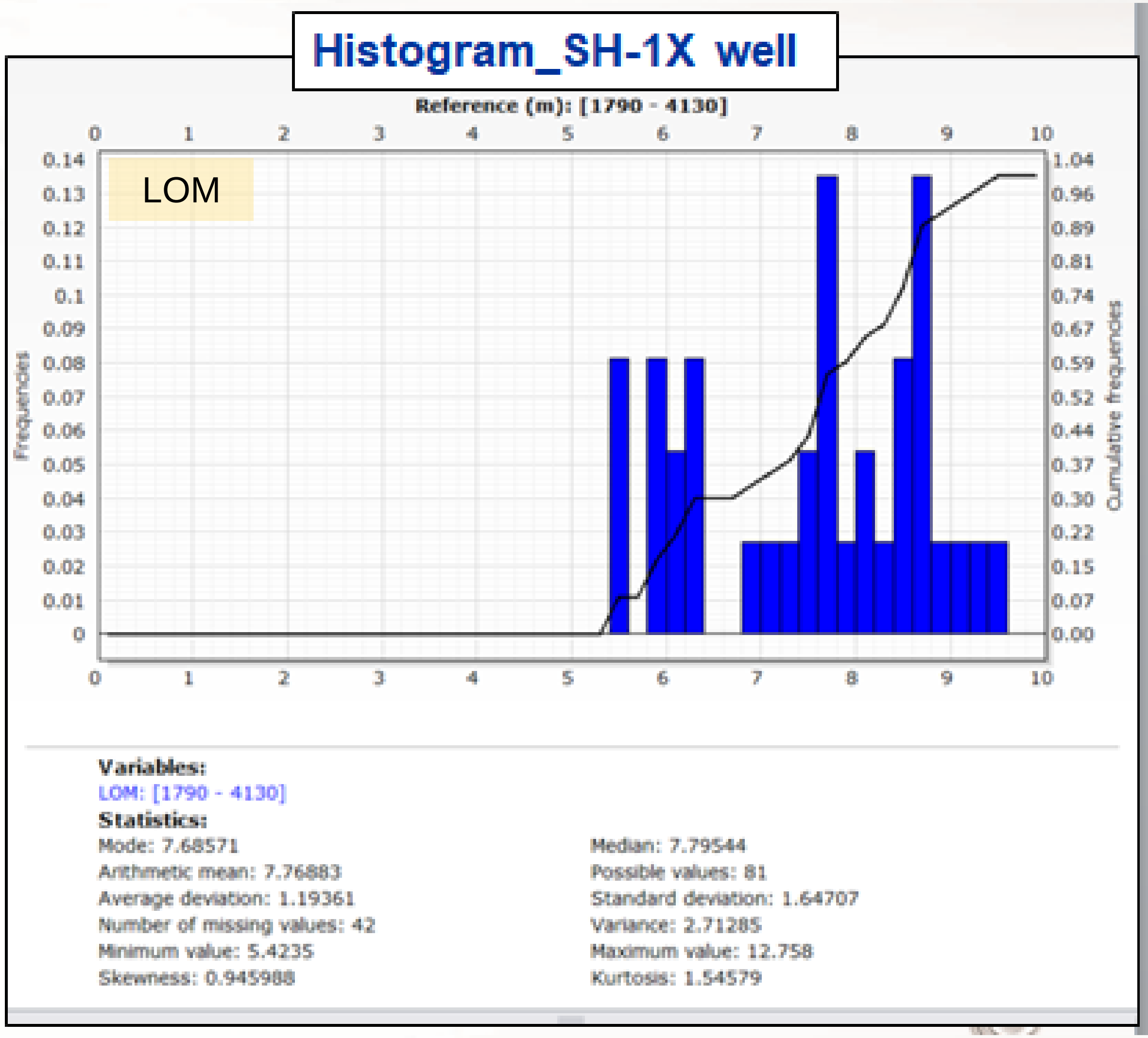


Ro<1 % in most samples in SH-1X well



A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN





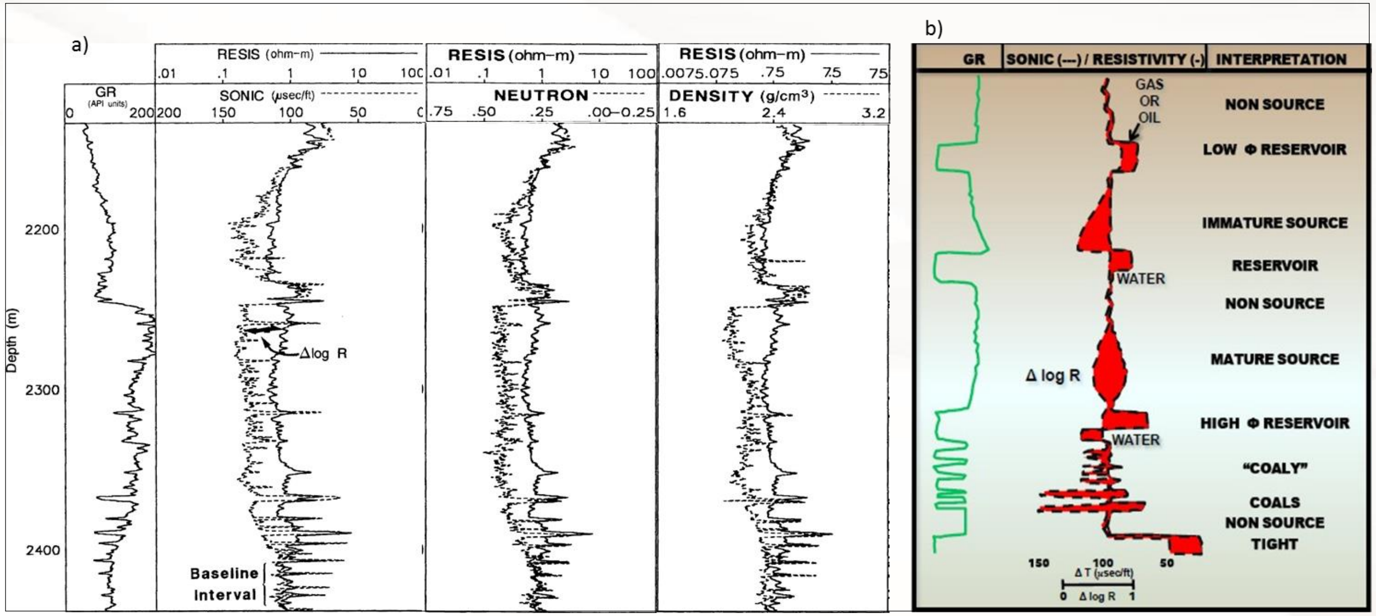
A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

$$\triangle \log R = \log_{10}(R/R_{baseline}) + 0.02 * (\triangle t - \triangle t_{baseline})$$

$$\triangle \log R_{neu} = \log_{10}(R/R_{baseline}) + 4 * (\Phi N - \Phi N_{baseline})$$

$$\triangle \log R_{Den} = \log_{10}(R/R_{baseline}) + 2.5 * (\rho_b - \rho_{baseline})$$

$$TOC = \triangle \log R \times 10^{(2.297 - 0.1688 \times LOM)}$$



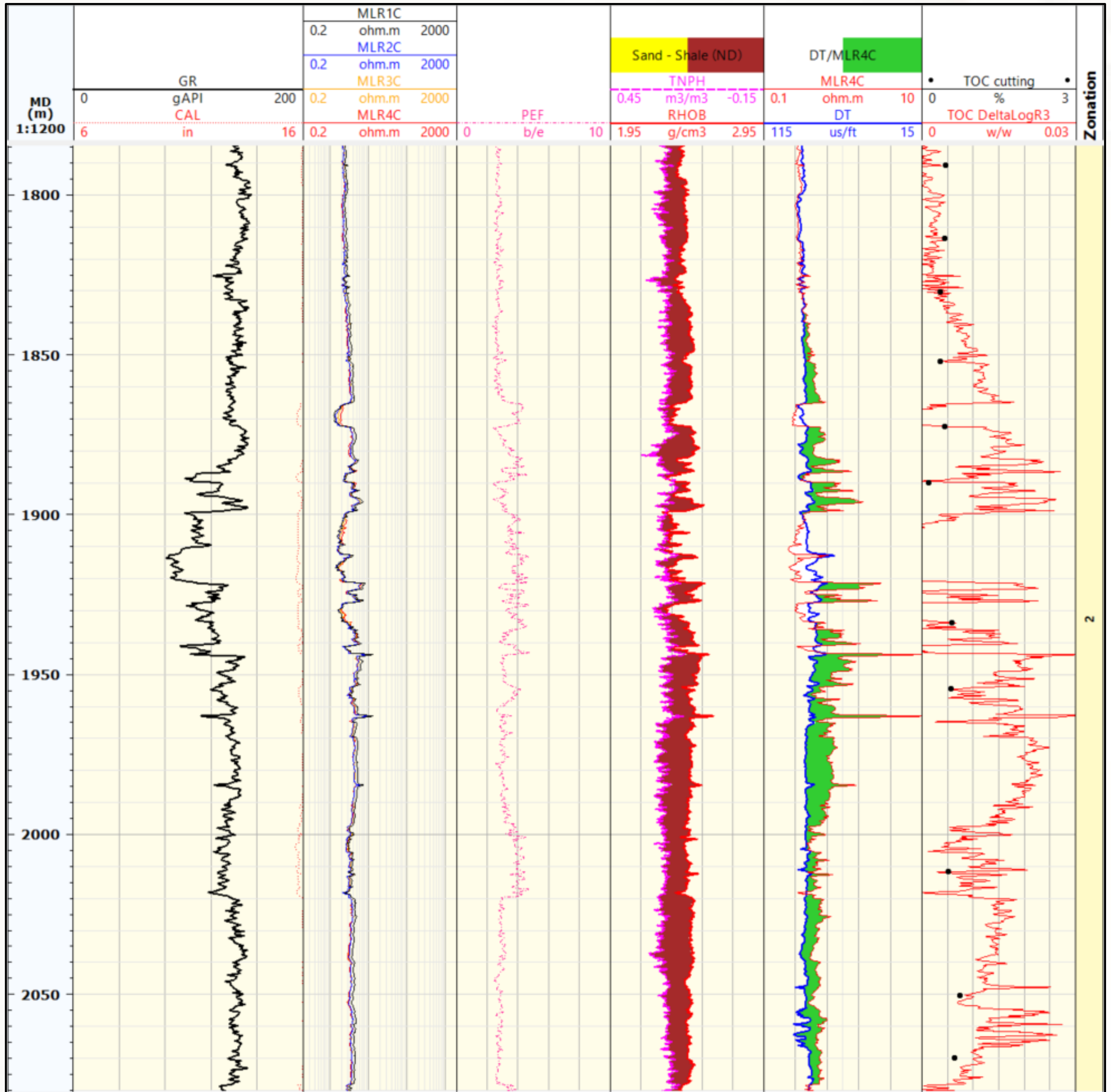
Delta log R method of Passey et al. (1990):

(i) Sonic/resistivity overlay showing Delta log R separation in the organic-rich interval;

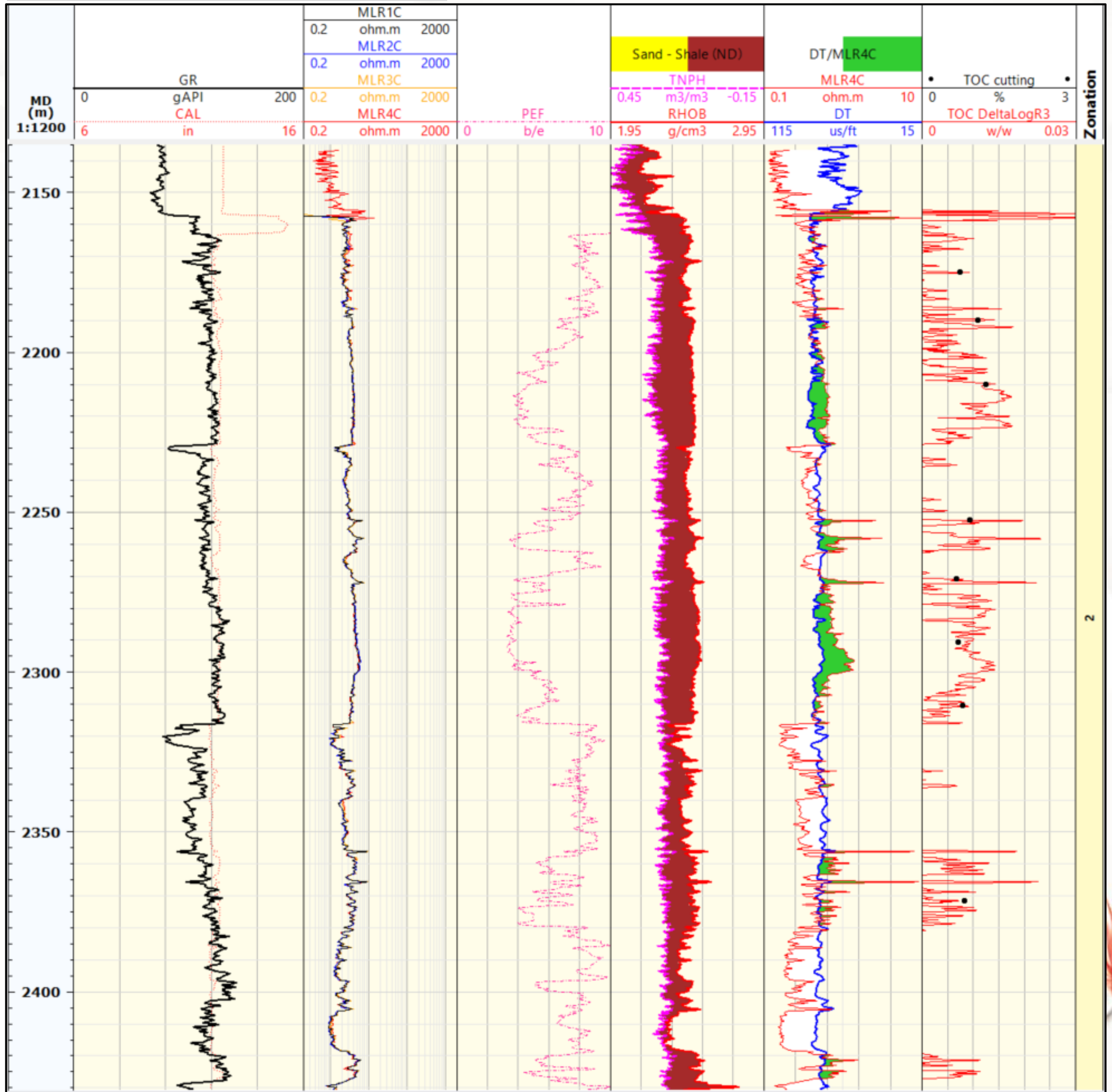
(ii) Schematic log showing sonic/resistivity overlay in a variety of situations

A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

Interval: 1785-2080m

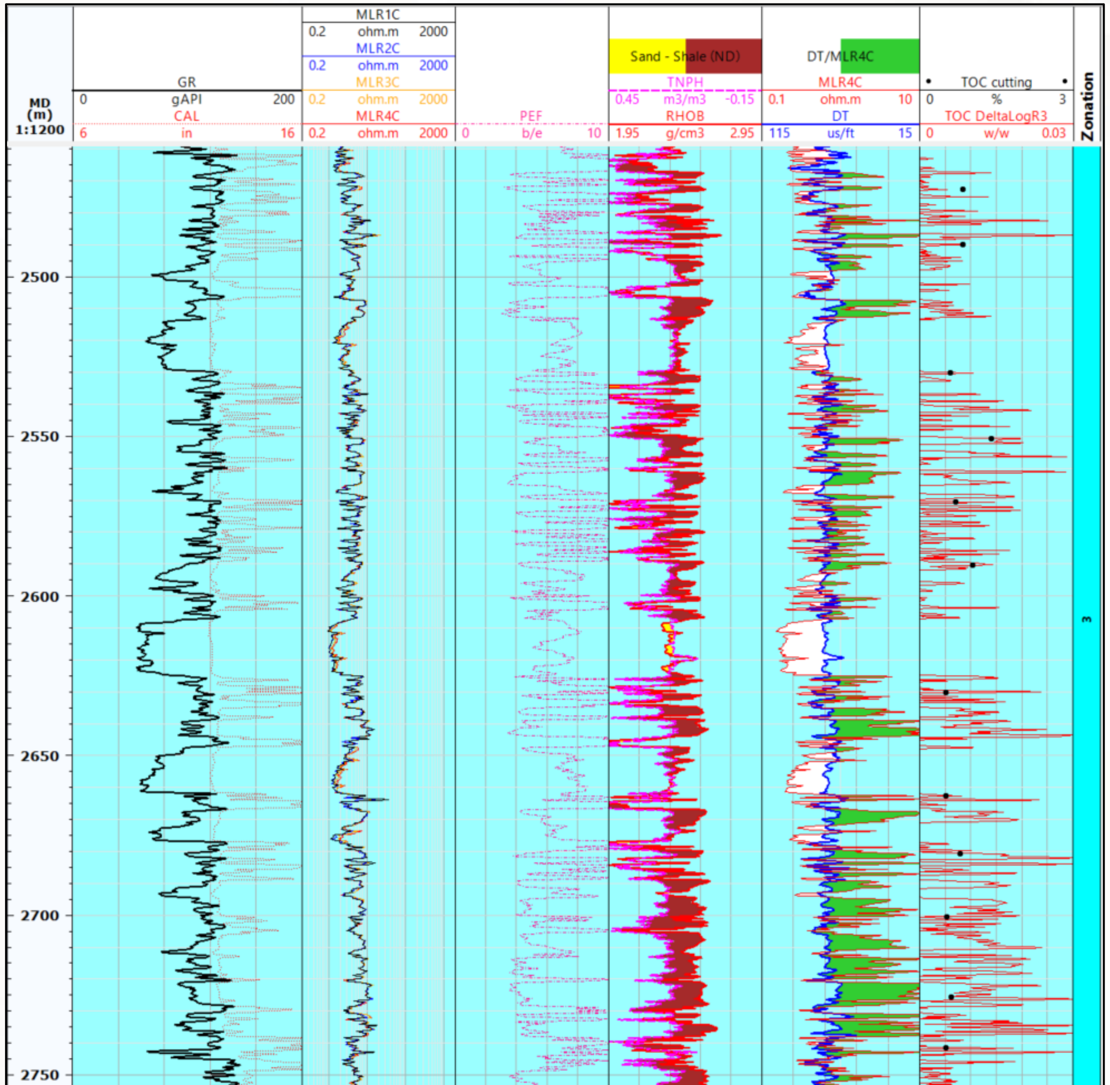


Interval: 2140-2430m

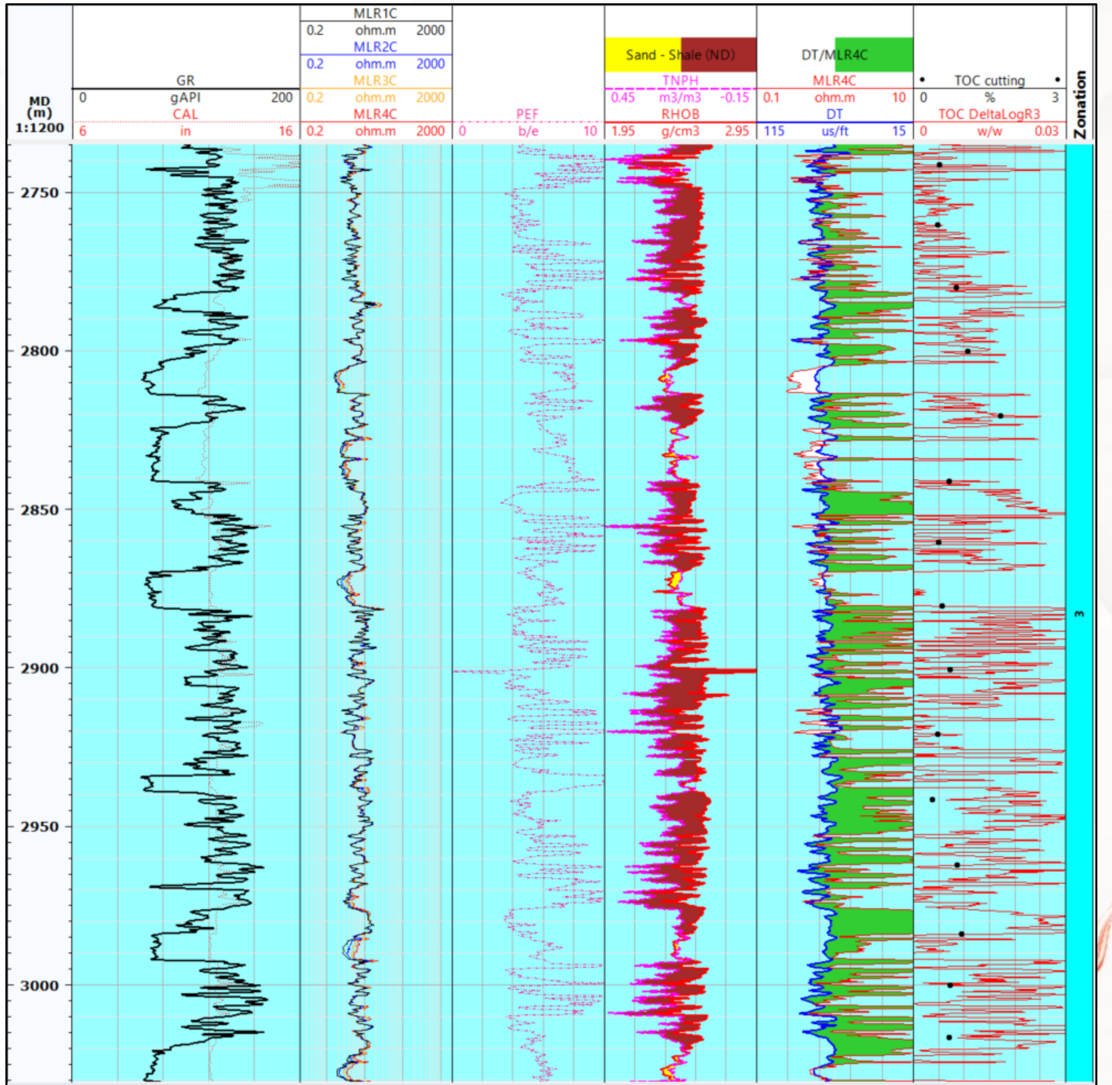


A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

Interval: 2430-2750m

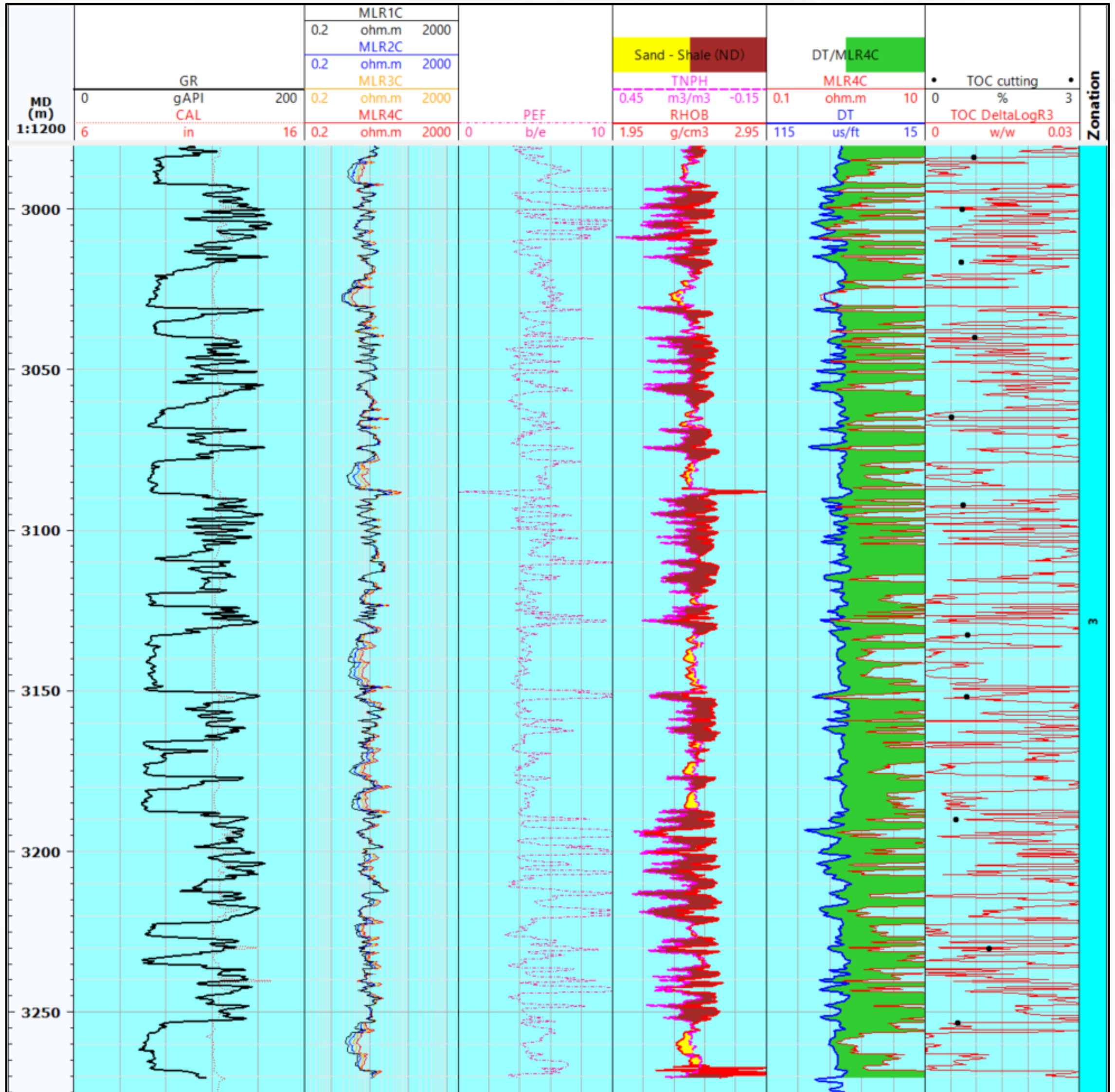


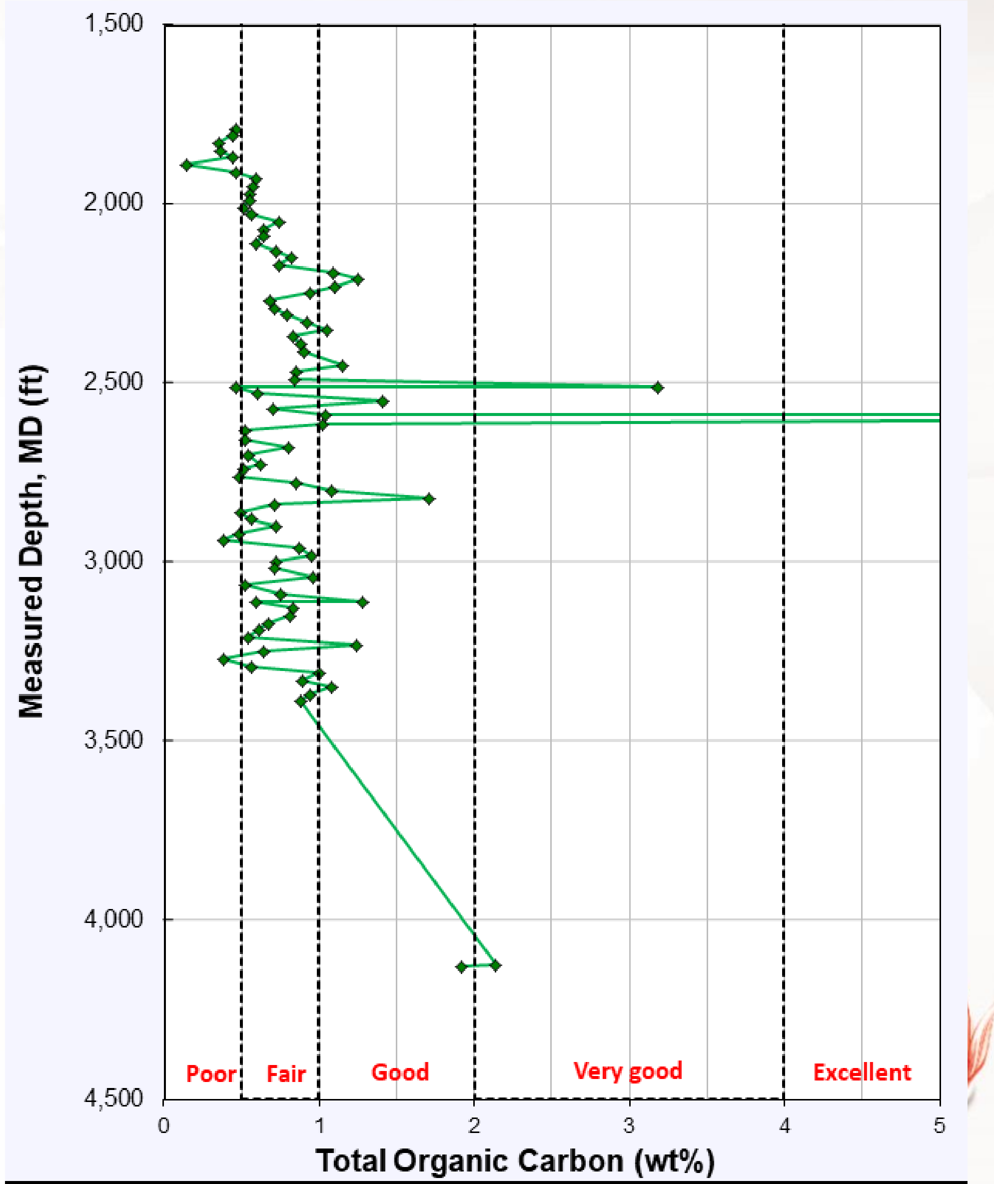
Interval: 2750-3030m



A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

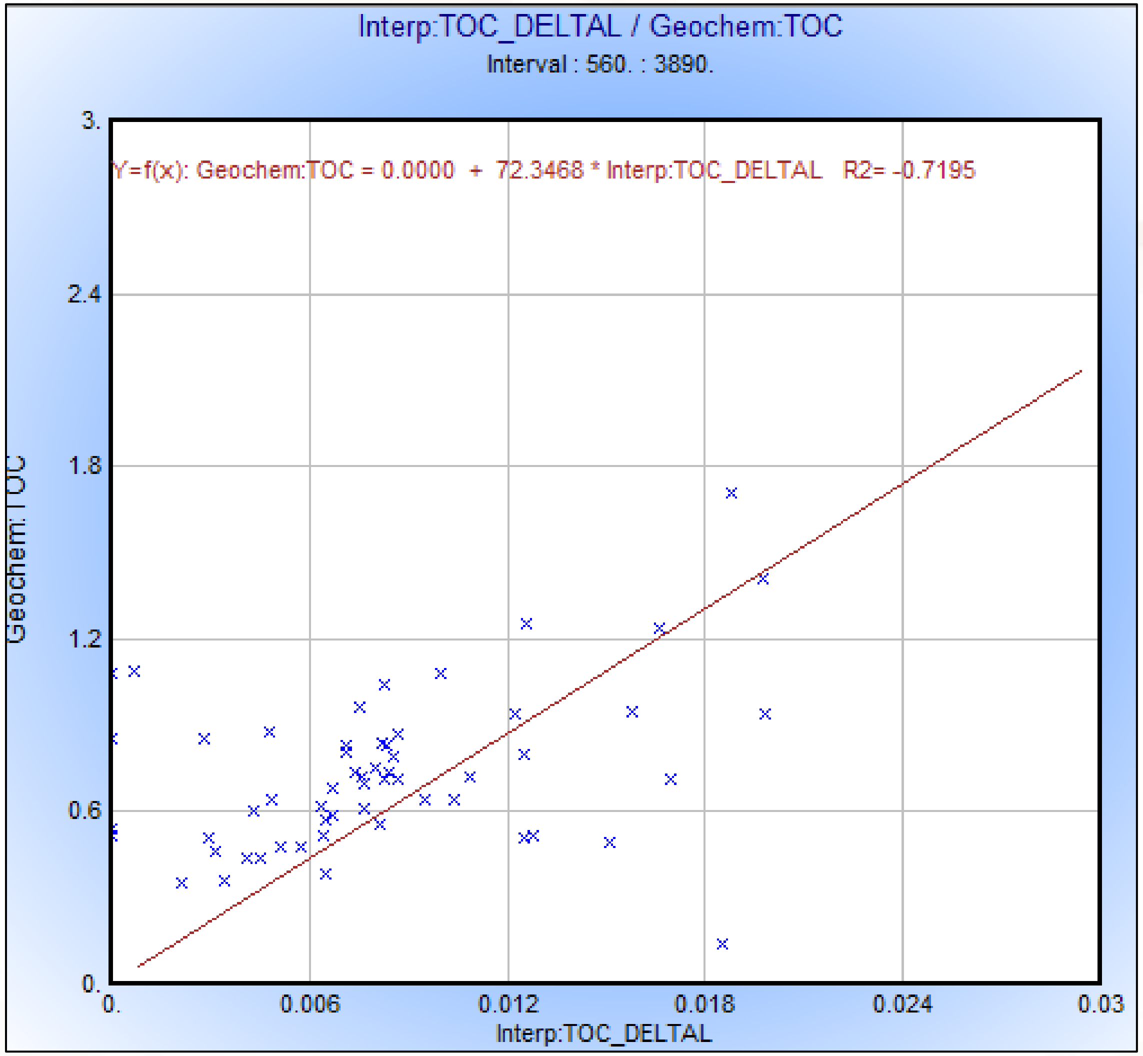
Interval: 3030-3270m





A CASE STUDY: CALCULATING TOC FOR SH-1X WELL, SONG HONG BASIN

Cross plot of Delta LogR TOC vs the measured TOC from cutting



05

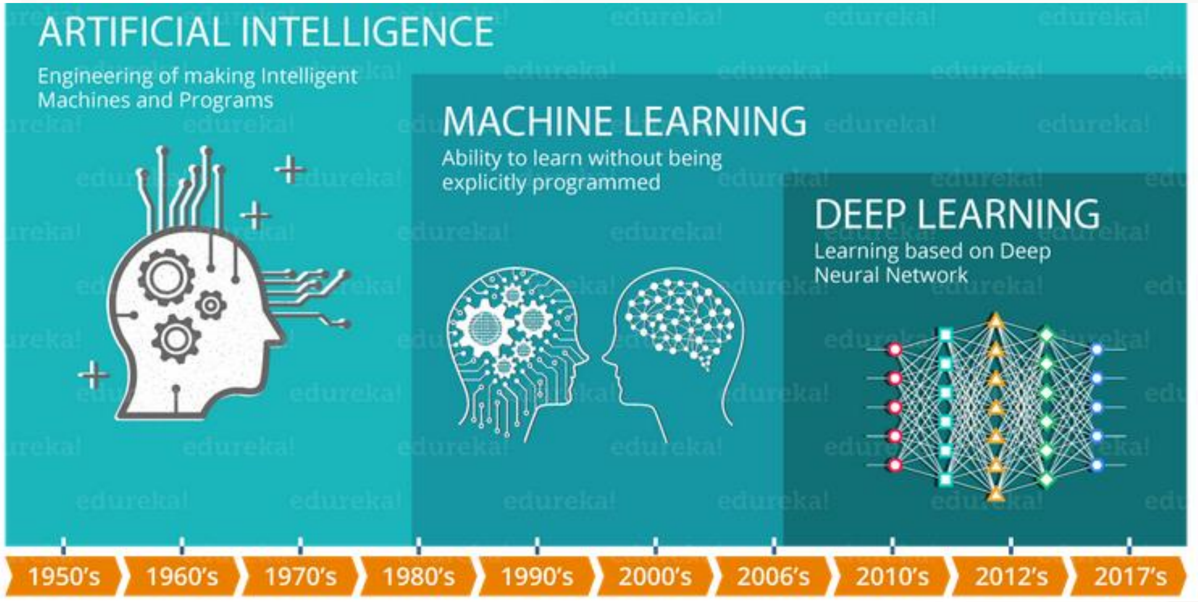
ESTIMATION OF TOC USING ARTIFICIAL INTELLIGENCE TECHNIQUES

ESTIMATION OF TOC USING AI TECHNIQUES

1. Artificial Intelligence (AI)

Artificial intelligence (AI) is wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. AI is an interdisciplinary science with multiple approaches, but advancements in machine learning and deep learning

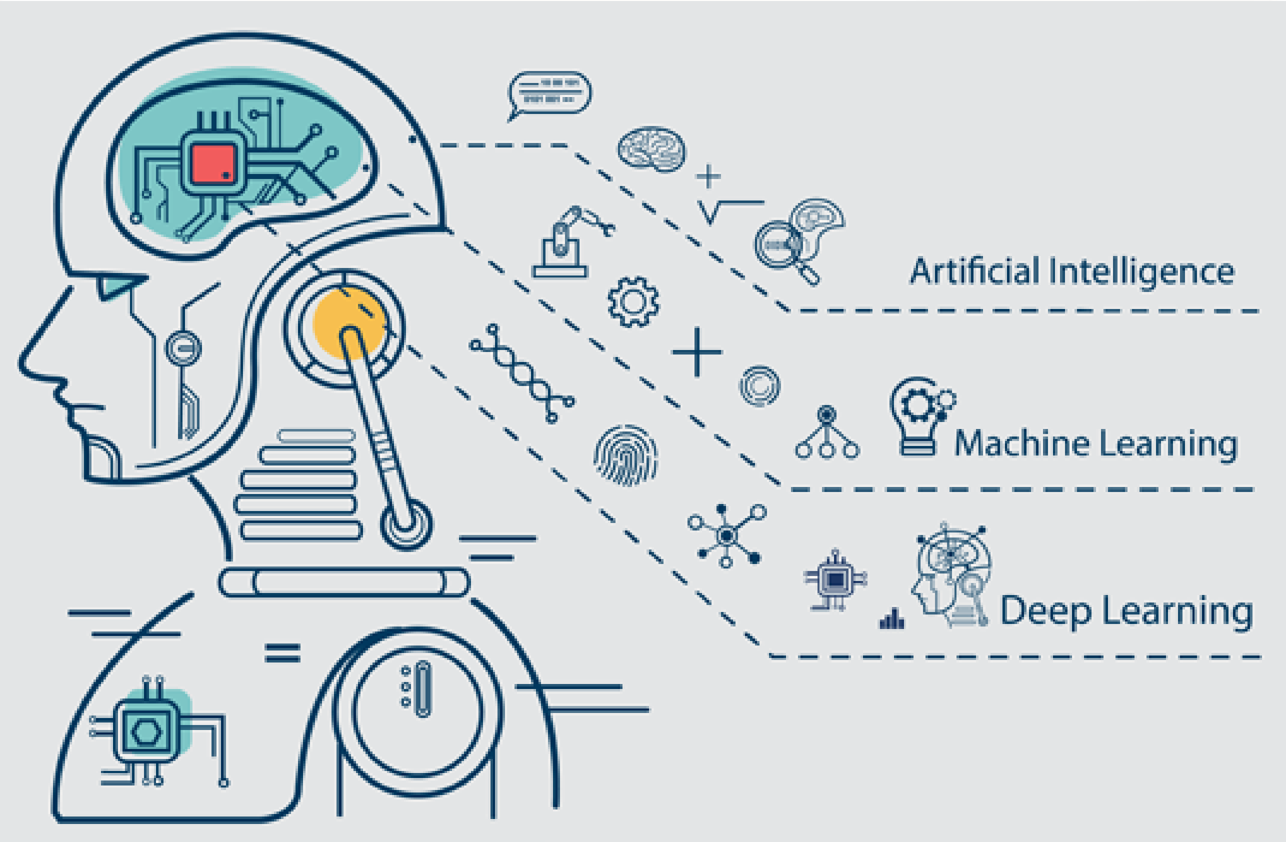
AI is an interdisciplinary science with multiple approaches, but advancements in **machine learning** and **deep learning** are creating a paradigm shift in virtually every sector of the tech industry.

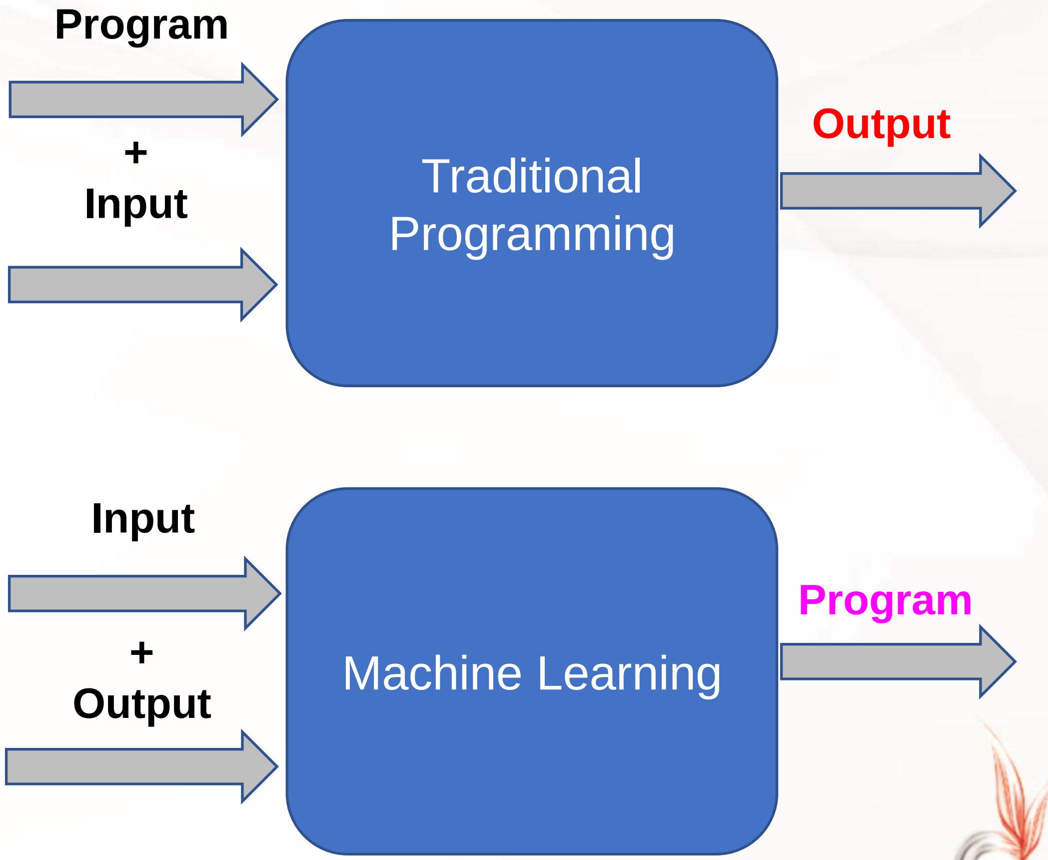


AI applies machine learning, deep learning and other techniques to solve actual problems

ESTIMATION OF TOC USING AI TECHNIQUES

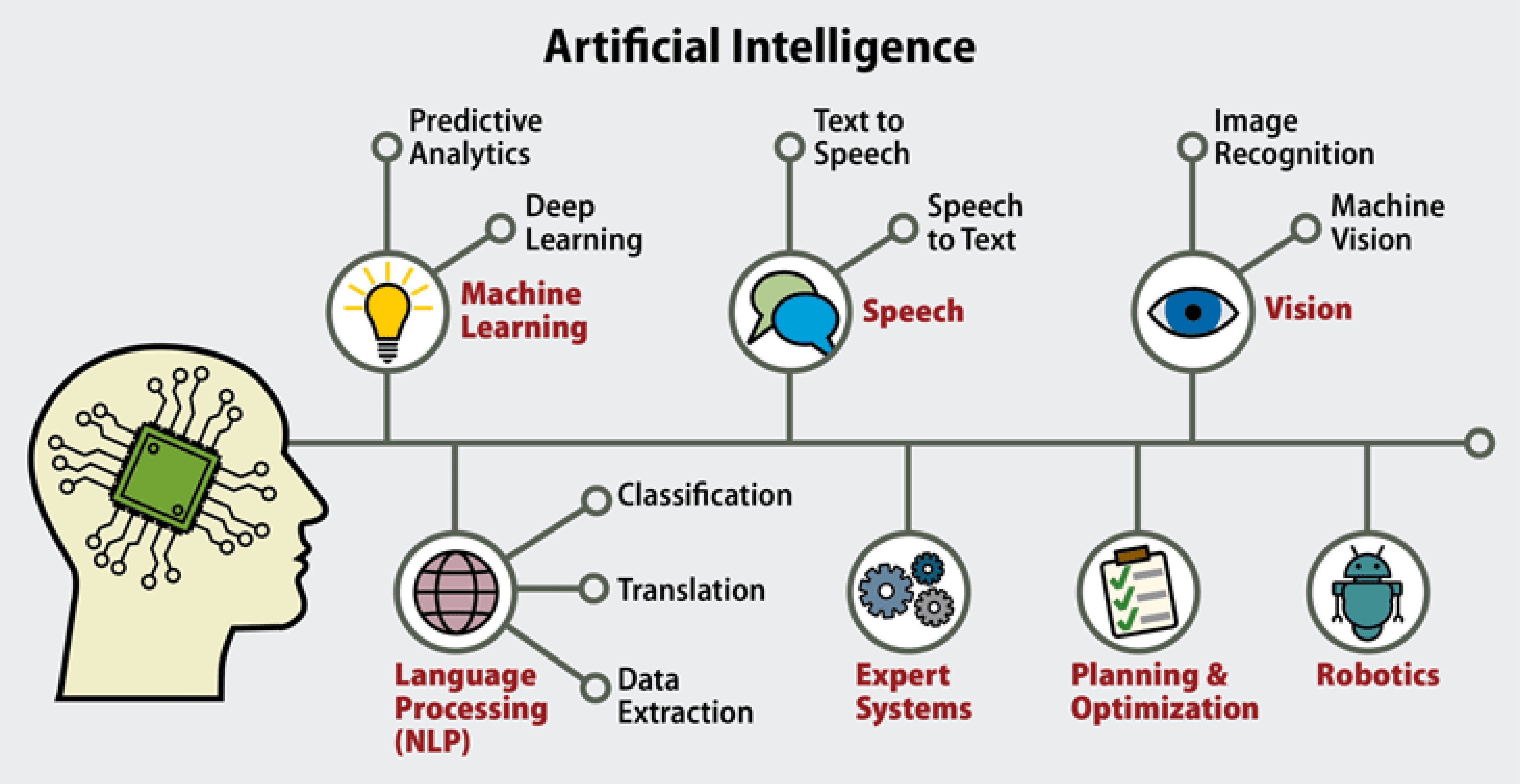
Comparison between regular programming and AI programming





ESTIMATION OF TOC USING AI TECHNIQUES

2. Branches of AI



ESTIMATION OF TOC USING AI TECHNIQUES

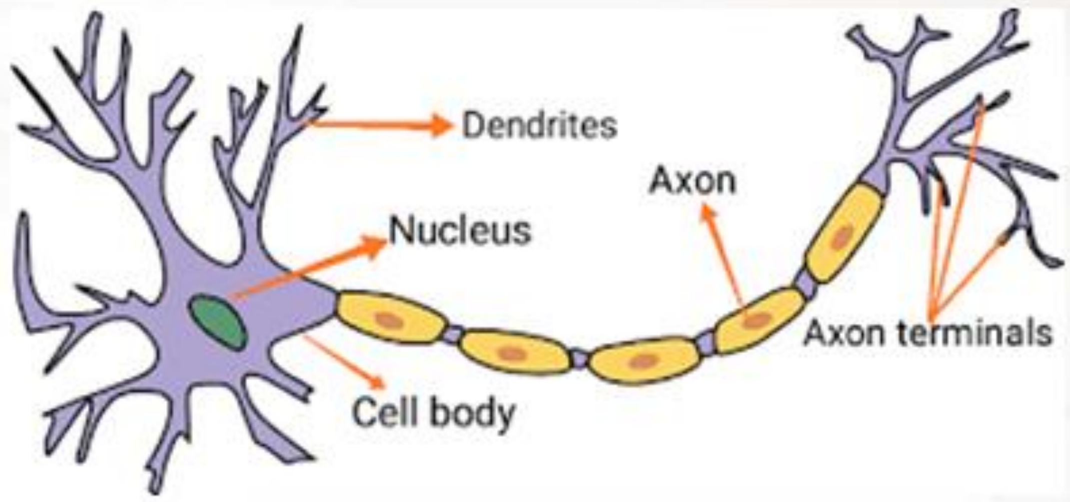
3. Some AI Techniques are being used for estimation of TOC

- ANN: Artificial Neural Network
- SVM: Support Vector Machine
- FNN: Functional Neural Network
- M-FIS: Mamdani fuzzy interference system
- TSK-FIS: Takagi-Sugeno-Kang fuzzy
- HNN: Hybrid Neural Network
- ANN-LM: Artificial Neural Network which based on Levenberg-Marquardt logarithm
- ELM: Extreme Learning Machine

ESTIMATION OF TOC USING ANN TECHNIQUE

4. Artificial Neural Network (ANN) for conventional and unconventional reservoirs

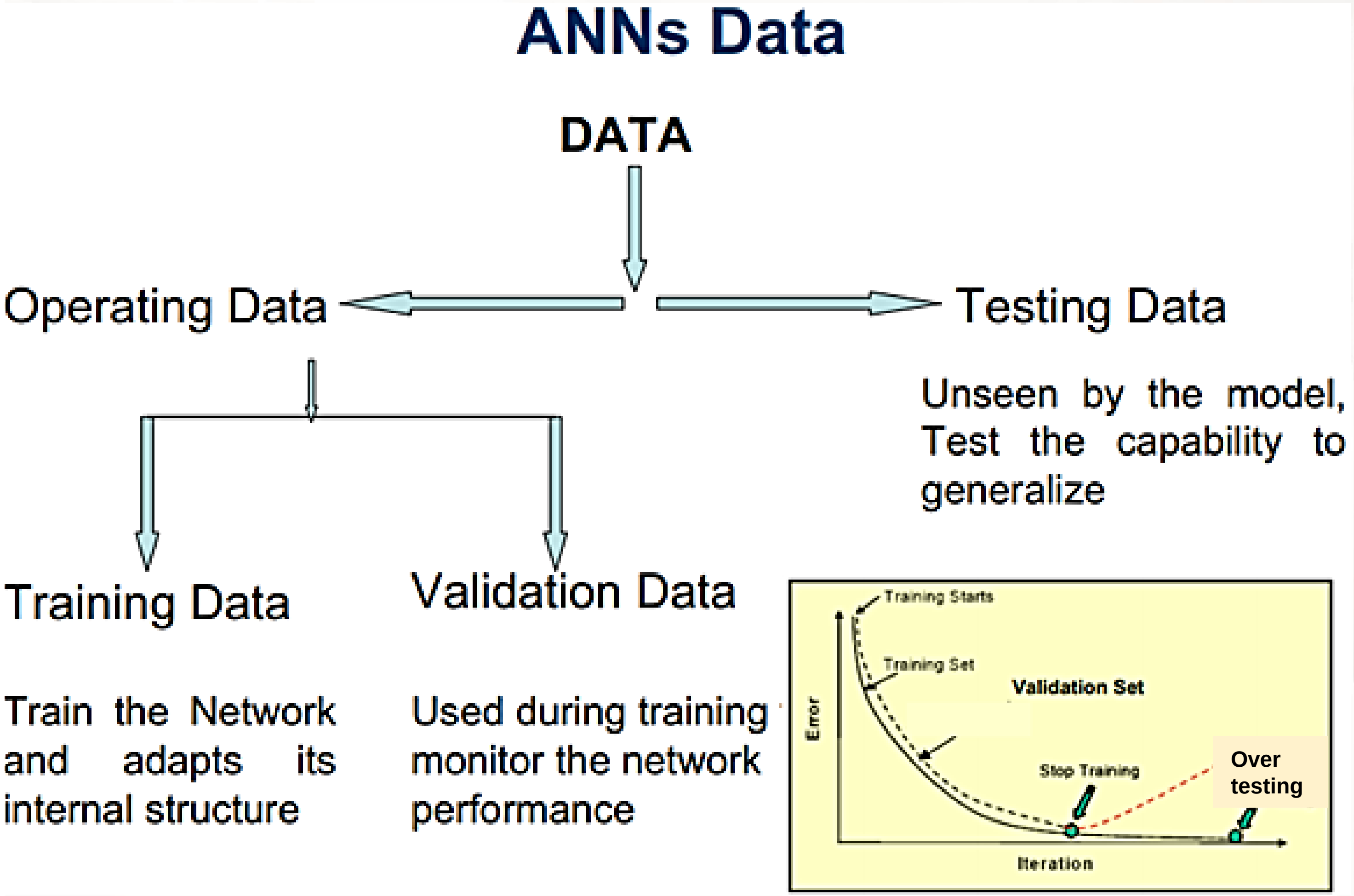
- ANN is an information processing system that roughly replicates the behaviour of a human brain by emulating the operations and connectivity of biological neurons
- It performs a human-like reasoning, learns the attitude and stores the relationship of the processes on the basis of a representative data set that already exists
- A series of connecting neuron weights are adjusted to fit a series of inputs to another series of known outputs. It means the neuron is learning.
- The adaptability, reliability and robustness of an ANN depend upon the source,range, quantity and quality of the data set.



ESTIMATION OF TOC USING ANN TECHNIQUE

How to divide the data?

- How to select the input parameters?
- How many hidden neurons?
- How many hidden layers?
- What transfer function?
- What learning algorithms?
- How to stop the model from training?
- How to scale method?



ANN workflow

Well logging interpretation
Input data: Integrating well log data for 1 well
Software: Techlog

↓

Well logging interpretation using cross-plot, seperation technique to determine lithology, organic shale intervals

↓

ANN modeling and Testing
Input data: selecting well log data from SH-1X well
Target output: interpreting the predict TOC and measured TOC
Software: MATLAB

↓

Design ANN model

↓

Training ANN with training data set

↓

Testing ANN with validating data set

↓

Comparing ANN model and selecting the optimal model

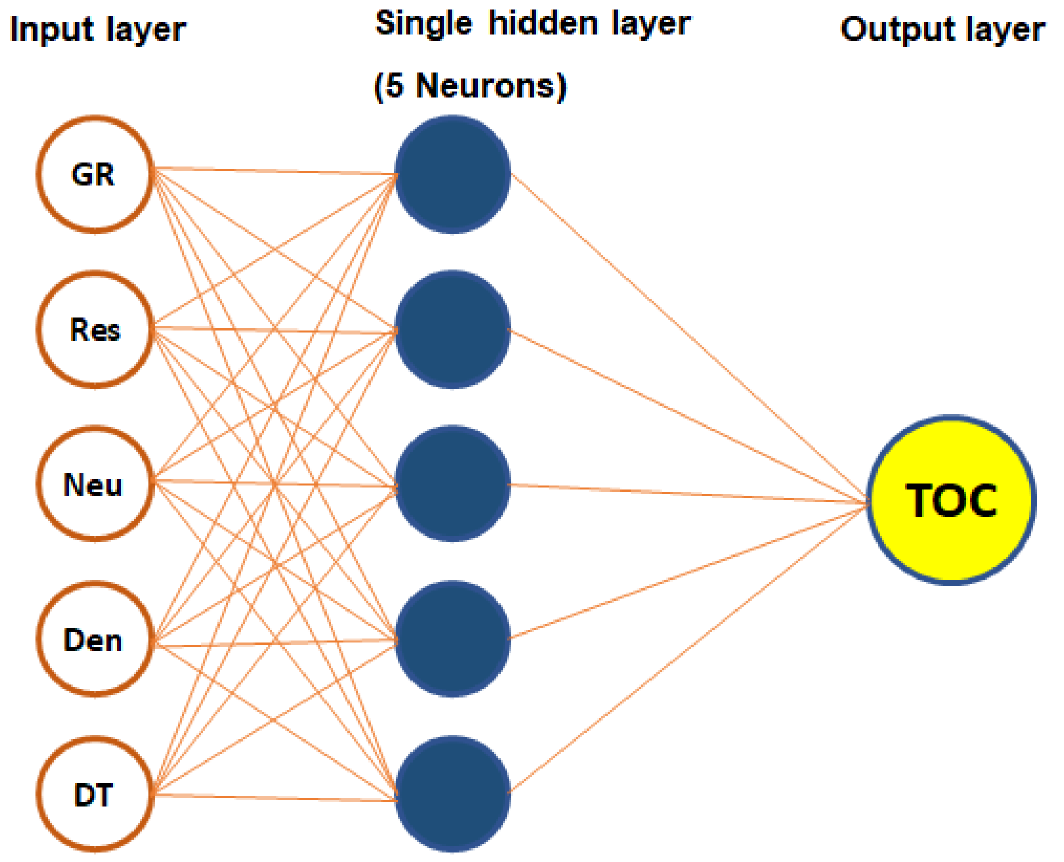
↓

Using selected ANN model to predict TOC

ESTIMATION OF TOC USING ANN TECHNIQUE

Designing structure for ANN model : A case study of SH-1X well, Song Hong basin

- Based on well log curves: GR, MLR, RHOB, TNPH, DT
- ANN was trained on the data collected from shales of SH-1X well
- The model was optimized using inserted for loops built in Matlab software to consider all combinations of the possible values of different designed parameters and the ratios of the training-to-testing data
- Optimization process, the parameters were found to optimize TOC predictability for the ANN model



ESTIMATION OF TOC USING ANN TECHNIQUE

Range of the parameters used for training the ANN model

Parameters					
	GR	**Res**	**Sonic**	**Den**	**TOC**
	(API)	(Ohm.m)	(µsec/ft)	(g/cm3)	(fraction)
Minimum	34.2	0.11	52.5	1.23	0
Maximum	150	101.2	140	2.98	0.099
Mean	113.6	2.5	92.9	2.31	0.013
Mode	115.5	0.98	79	2.46	0.001

Optimized parameters for the proposed the ANN model

Parameter	Value
Learning function	Trainlm (updates weights & bias values according to Levenberg-Marquardt optimization)
Transfer function	Tansig (calculate a layer's output from its net input. tansig (N) takes one input, N - S x Q matrix of net input (column) vector
Number of hidden layers	1
Number of neutrons	5

ESTIMATION OF TOC USING ANN TECHNIQUE

Log data collection and preparation:

- 84 data set from the well SH-1X
- The training set was evaluated statistically to remove all unrealistic values and outliers
- The outliers are removed based on the standard deriviation in range of +/- 3.0
- After pre-processing, 58 of 84 data sets were selected to train the ANN model based on variables: GR, resistivity, density, sonic. The input parameters were selected based on their relative effect on the measured TOC
- TOC is strong function GR, Resistivity and density

The relative importance of the different parameters considered to learn the ANN model

ESTIMATION OF TOC USING ANN TECHNIQUE

Building ANN model:

- Coding for this ANN model is under processing;
- The preliminary results show that the training set gave the best prediction of the measured from above *optimized parameters for the proposed the ANN model ;*
- The equations are applied for the model:

$$\frac{Y - Y_{min}}{Y_{max} - Y_{min}} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

$$Y = \left(\frac{X - X_{min}}{X_{max} - X_{min}}\right)(Y_{max} - Y_{min}) + Y_{min}$$

$$TOC = \left[\sum_{i=1}^{N} w_{2-i}\,\text{tansig}\left(\sum_{j=1}^{J} w_{1-i,j}Y_j + b_{1i}\right)\right] + b_2$$

Y: normalized input parameter
Ymin=-1; Ymax=1
X: input parameter (GR, Res, density, sonic)
Xmin=minimum input value; Xmax=maximum input value

N: total number of neurons
J: number of inputs (GR, Res, sonic, density logs)
w1 and b1: weight and bias of hidden

ESTIMATION OF TOC USING ANN TECHNIQUE

The proposed ANN-based weights and biases for TOC calculations

		Input layer					Output layer	
		Weights(w1)				Biases (b1)	Weights (w2)	Bias (b2)
		j=1	j=2	j=3	j=4			
No. of neurons	i=1	0.9517	0.5817	0.9676	-2.5309	- 0.2742	-1.7182	-1.2152
	i=2	0.5742	0.6430	0.7720	-2.1296	- 0.0267	2.2211	
	i=3	5.4001	0.7938	1.0230	2.9429	0.7237	0.1883	
	i=4	0.7955	- 0.0550	- 0.4142	0.2749	1.2092	-0.9094	
	i=5	-0.1984	7.8703	- 0.4421	-0.1181	8.9550	1.7738	

CONCLUSIONS

ANN model was proposed to estimate TOC for shales in the SH-1X well using log data. Some obtained results can be drawn:

- Estimating TOC from well logging data shows good match with measured TOC in clean shale intervals;
- TOC emperical correlation was extracted based on the weights and biases of the optimized ANN model. The equation can be used to estimate the TOC based on log data with a high accuracy without need for ANN model
- All parameters are provided for training ANN model
- ANN model is under proccessing and testing, however, the initial results show a better TOC estimation compared to other methods by high coefficient of determination.

THANK YOU

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