Stochastic TOC modeling for East African Rift System Lakes, a possible pre-salt analogous

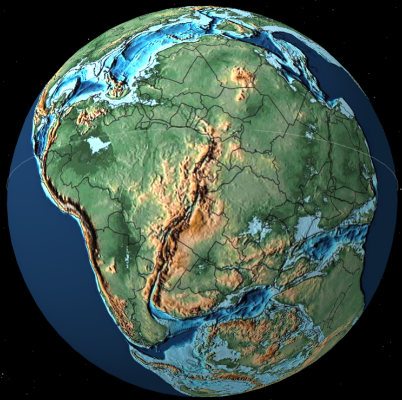
Carreira,V.R.[1]; Venancio,I.M.[1]; Belem,A.L.[1]; Nascimento,R.A.[1]; Affonso,P.V.A.[1]; Viegas,I.A.F.S.[2]; Spigolon,A.L.D.[2]; Albuquerque,A.L.S.[1]

1 Federal Fluminense University - UFF (in Portuguese)
2 PETROBRAS

August 11, 2023

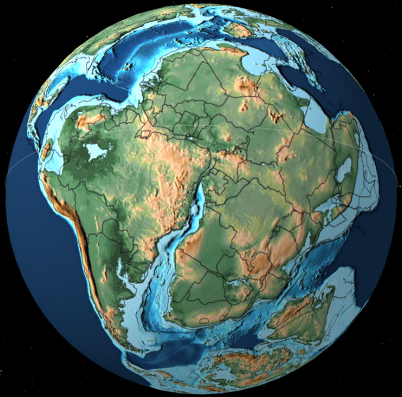
... somewhere in the ancient earth ...

... somewhere in the ancient earth ...



150 My ago

... somewhere in the ancient earth ...



120 My ago

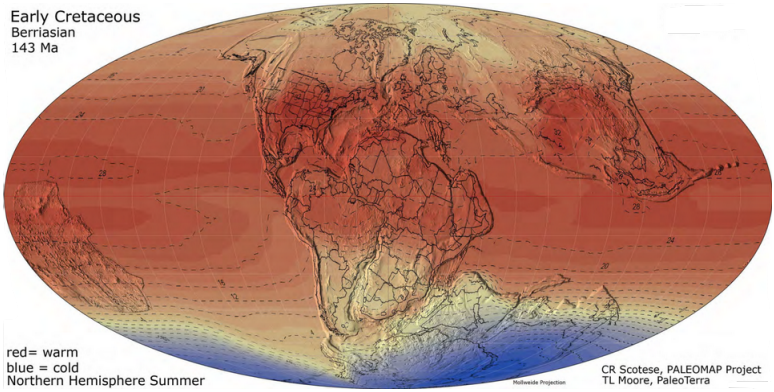


Figure: 143My ago, lakes were formed. (Scotese, 2013)

$$TOC = f(\alpha, \gamma, \delta, ...)$$

$$TOC = \cancel{f(\alpha, \gamma, \delta, \ldots)} \rightarrow unknow$$

Modern Analogous

Modern Analogous

Modern Analogous

Considering an initial Rift perspective

Objectives

- Define the main variables that interact in actual lakes;

Objectives

- Define the main variables that interact in actual lakes;
- Such lakes should be a pre-salt analogous;

Objectives

- Define the main variables that interact in actual lakes;
- Such lakes should be a pre-salt analogous;
- Predictive TOC model for lakes;

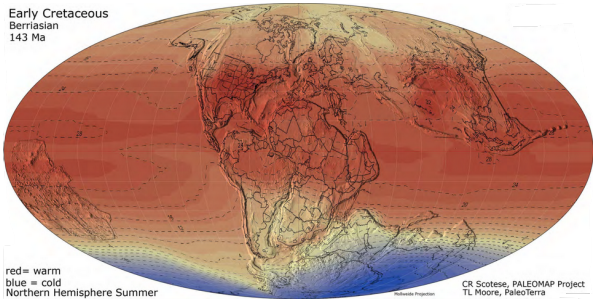
Objectives

- Define the main variables that interact in actual lakes;
- Such lakes should be a pre-salt analogous;
- Predictive TOC model for lakes;
- Create and publicize a data table used to mimetic TOC in real lake systems;

Objectives

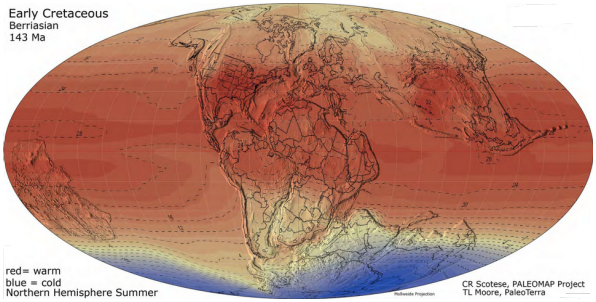
- Define the main variables that interact in actual lakes;
- Such lakes should be a pre-salt analogous;
- Predictive TOC model for lakes;
- Create and publicize a data table used to mimetic TOC in real lake systems;
- Define the best membership function for the studied lakes.

Pre-salt lakes



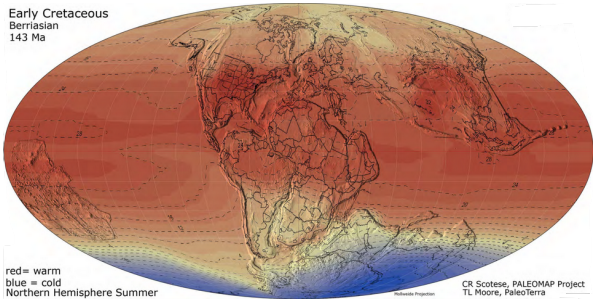
- This distinctive set of lakes existed throughout the Lower Cretaceous

Pre-salt lakes



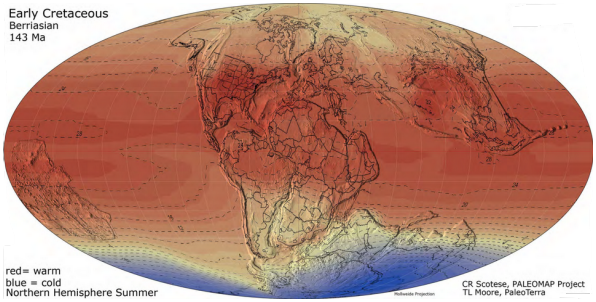
- This distinctive set of lakes existed throughout the Lower Cretaceous
- It has a wide distribution and its record includes the sedimentary basins of the eastern margin as well as the sedimentary basins of the equatorial margin

Pre-salt lakes



- This distinctive set of lakes existed throughout the Lower Cretaceous
- It has a wide distribution and its record includes the sedimentary basins of the eastern margin as well as the sedimentary basins of the equatorial margin
- The record of large layers of salt is not decisive for the existence of these lakes.

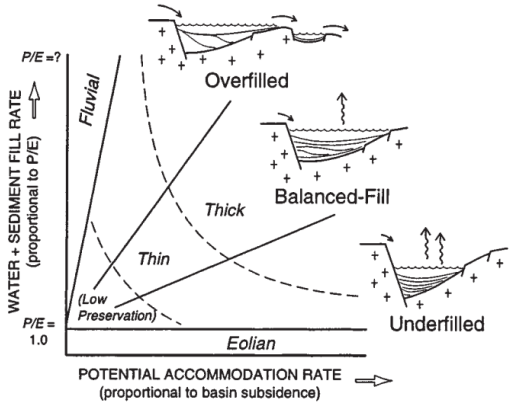
Pre-salt lakes



- This distinctive set of lakes existed throughout the Lower Cretaceous
- It has a wide distribution and its record includes the sedimentary basins of the eastern margin as well as the sedimentary basins of the equatorial margin
- The record of large layers of salt is not decisive for the existence of these lakes.

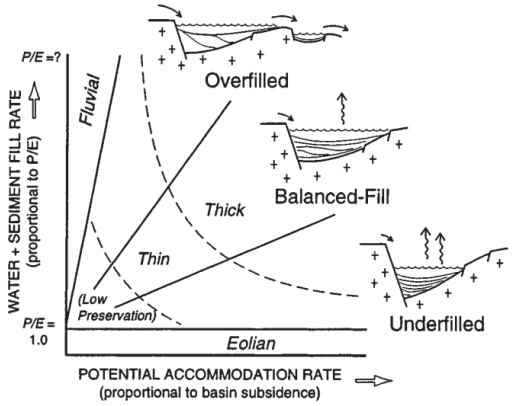
(Kelts, 1988; Talbot, 1988; Gonçalves, 2001; Wright and Rodriguez, 2018; Boyd et al., 2015; Neves et al., 2019)

Pre-salt lakes



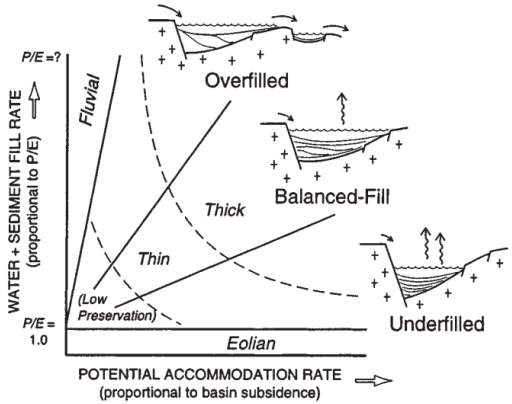
- The relation precipitation/evaporation induces the preservation factor;

Pre-salt lakes



- The relation precipitation/evaporation induces the preservation factor;
- The sedimentation rate, distance of the source area, and the depths of the lake have a direct impact on the preservation factor;

Pre-salt lakes

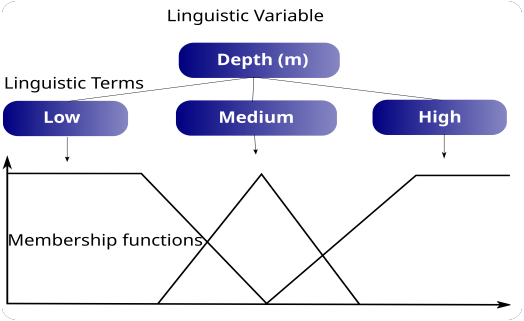


- The relation precipitation/evaporation induces the preservation factor;
- The sedimentation rate, distance of the source area, and the depths of the lake have a direct impact on the preservation factor;
- Factors such as pH, dissolved oxygen, and primary productivity warrant consideration.

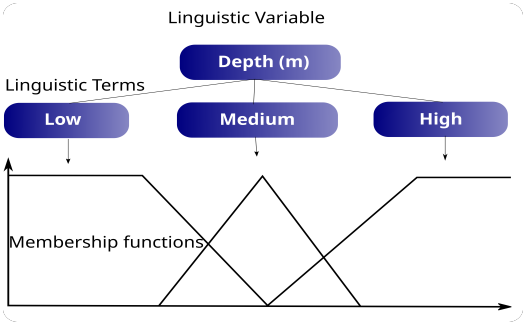
(Kelts, 1988; Talbot, 1988; Gonçalves, 2001; Wright and Rodriguez, 2018; Boyd et al., 2015; Neves et al., 2019)

Fuzzy system

- Fuzzy sets are defined by an interval within a linguistic variable

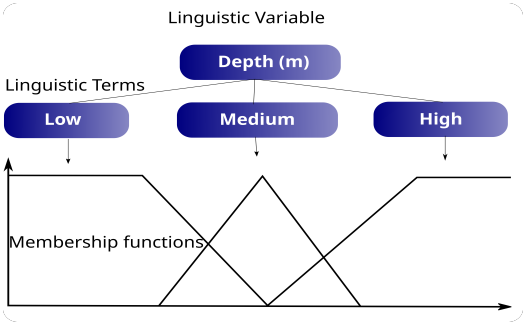


Fuzzy system



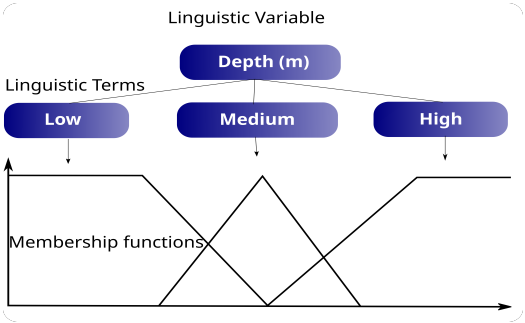
- Fuzzy sets are defined by an interval within a linguistic variable
- Linguistic variables are known as antecedents or consequents depending on the inputs or outputs of the model

Fuzzy system



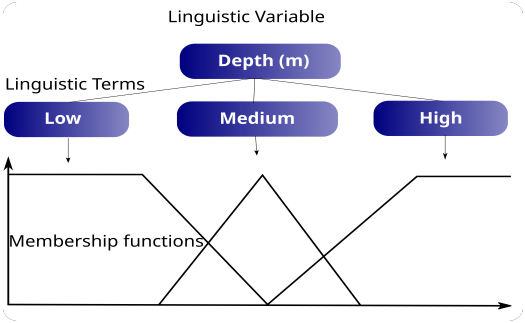
- Fuzzy sets are defined by an interval within a linguistic variable
- Linguistic variables are known as antecedents or consequents depending on the inputs or outputs of the model
- These ranges are defined within the linguistic terms

Fuzzy system



- Fuzzy sets are defined by an interval within a linguistic variable
- Linguistic variables are known as antecedents or consequents depending on the inputs or outputs of the model
- These ranges are defined within the linguistic terms
- Each linguistic term is related to each other through a membership function

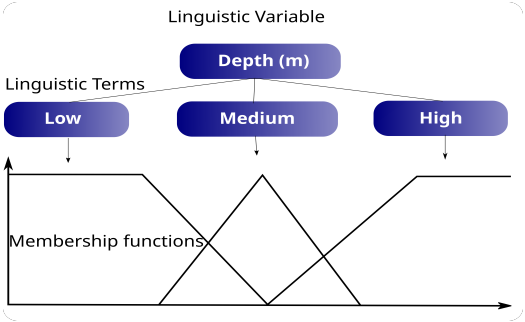
Fuzzy system



- Fuzzy sets are defined by an interval within a linguistic variable
- Linguistic variables are known as antecedents or consequents depending on the inputs or outputs of the model
- These ranges are defined within the linguistic terms
- Each linguistic term is related to each other through a membership function
- There is no formal basis for determining which is the best membership function for each linguistic variable.

11

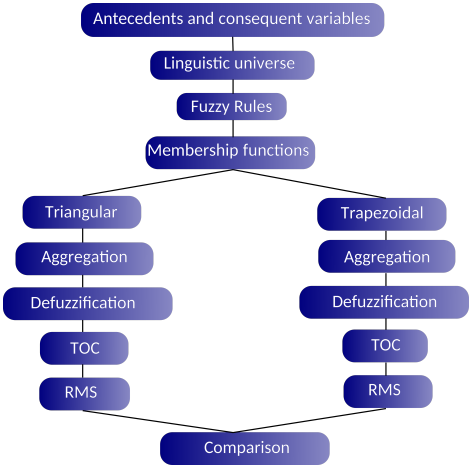
Fuzzy system



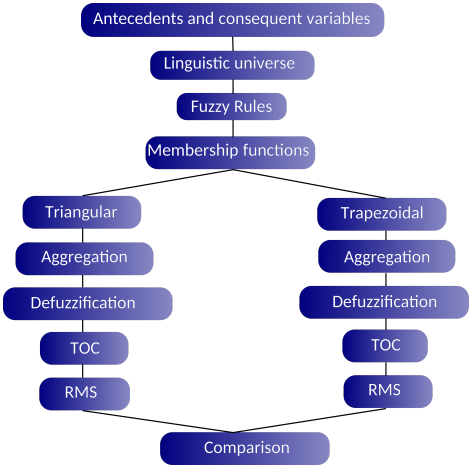
- Fuzzy sets are defined by an interval within a linguistic variable
- Linguistic variables are known as antecedents or consequents depending on the inputs or outputs of the model
- These ranges are defined within the linguistic terms
- Each linguistic term is related to each other through a membership function
- There is no formal basis for determining which is the best membership function for each linguistic variable.

(Jafelice et al., 2012; Warner et al., 2019; Siddiq et al., 2021)

Methodological flowchart



Methodological flowchart



$$RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \hat{x}_i)^2}$$

Table: East African Lakes Database. In red is TOC, defined as the model consequent variable. (Talbot, 1988; Bronikowska and Pisarska, 2021; Hamilton et al., 2016)

Lake	TOC	AD	MD	pH	O_2	SR	GRA	SEL	PP
Edward	11.62	17	112	9.10	2.50	2.8	0.06	1	43.30
Motubu	2.81	70	85	8.90	0.02	0.9	0.2	25	600
Kivu	7.14	240	480	8.60	11.76	8.00	0.10	0.02	264
Tanganyika	4.81	572	1470	8.30	9.16	1.00	0.002	0.02	1.40
Victoria	11.23	40	80	9.30	0.12	0.82	0.002	0.02	6.25

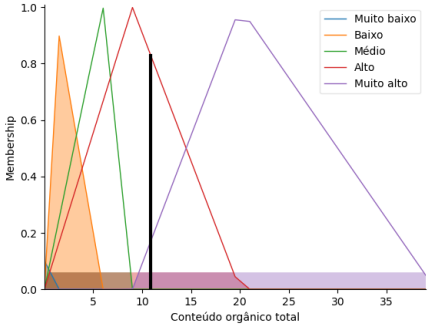
where TOC is Total Organic Carbon in $\%$, AD is average depth in m, MD is maximum depth in m, SR is sedimentation rate $(cm/kyear)$, GRA is grain size deposit in mm, SEL grain selection in mm, PP is primary productivity in $(gC/m^2/year)$.

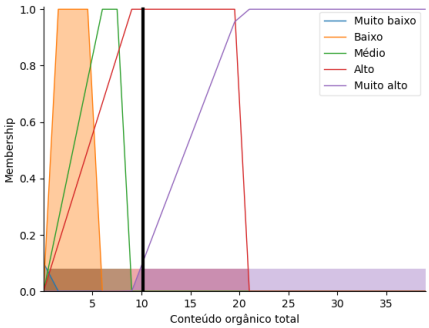
Victoria Lake

Classificação (COT) %	
Muito baixo	0.1-1
Baixo	1-6
Médio	6-9
Alto	8-20
Muito alto	>20

Victoria Lake

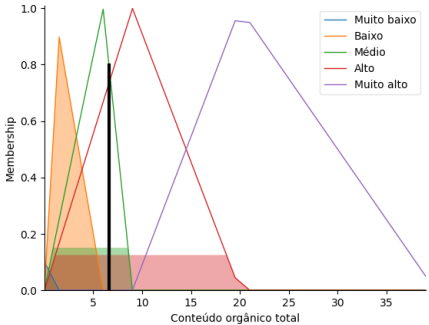
Classificação (COT) %	
Muito baixo	0.1-1
Baixo	1-6
Médio	6-9
Alto	8-20
Muito alto	>20

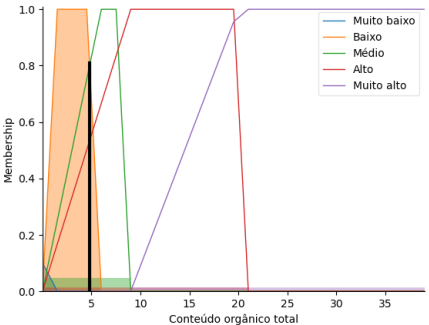




Tanganyika Lake

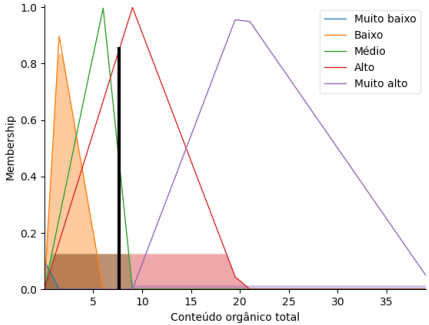
Classificação (COT) %	
Muito baixo	0.1-1
Baixo	1-6
Médio	6-9
Alto	8-20
Muito alto	>20

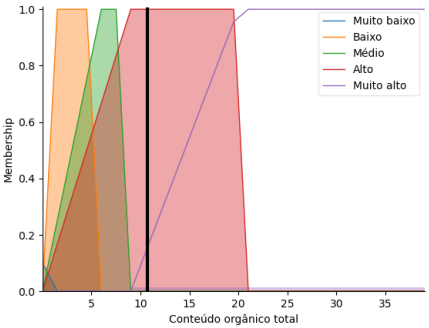




Kivu Lake

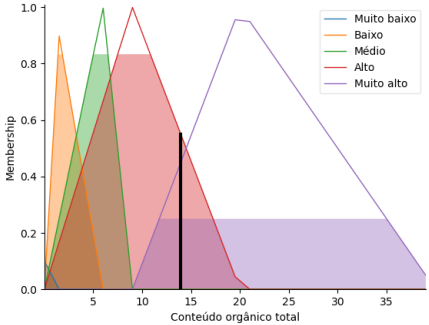
Classificação (COT) %	
Muito baixo	0.1-1
Baixo	1-6
Médio	6-9
Alto	8-20
Muito alto	>20

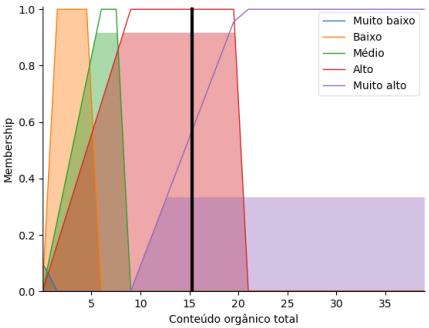




Edward Lake

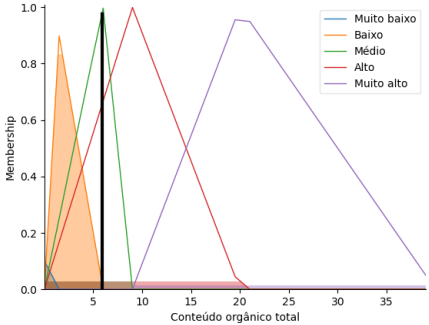
Classificação (COT) %	
Muito baixo	0.1-1
Baixo	1-6
Médio	6-9
Alto	8-20
Muito alto	>20





Motubu Lake

Classificação (COT) %	
Muito baixo	0.1-1
Baixo	1-6
Médio	6-9
Alto	8-20
Muito alto	>20



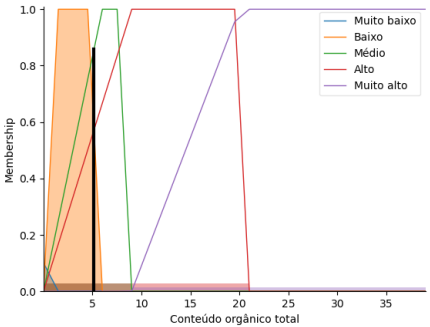


Table: Results

Lake	membership	$TOC_{obs}(\%)$	$TOC_{calc}(\%)$	RMS $(\%)$
Edward	triangular	11.62	13.95	2.33
Motubu	triangular	2.81	5.89	3.07
Kivu	triangular	7.14	7.67	0.53
Tanganyika	triangular	4.81	4.67	0.13
Victoria	triangular	11.23	10.87	0.36
Edward	trapezoidal	11.62	15.24	3.62
Motubu	trapezoidal	2.81	5.15	2.34
Kivu	trapezoidal	7.14	10.72	3.58
Tanganyika	trapezoidal	4.81	4.79	0.01
Victoria	trapezoidal	11.23	10.14	1.08

Some conclusions

- The simulations held for the East African Lake Systems showed good results for TOC estimation when a lake TOC function is not known.

Some conclusions

- The simulations held for the East African Lake Systems showed good results for TOC estimation when a lake TOC function is not known.
- The TOC concentration is better estimated when triangular membership functions are applied.

Some conclusions

- The simulations held for the East African Lake Systems showed good results for TOC estimation when a lake TOC function is not known.
- The TOC concentration is better estimated when triangular membership functions are applied.
- Results indicates that the organic matter contents can be estimated considering important environmental variables such as primary productivity (maximum of 600 gC/m2/year) and dissolved oxygen, but also when geological parameters such as sedimentation rate, granulometry, and selection are considered.

References

Boyd, A., Souza, A., Carneiro, G., Machado, V., Trevizan, W., Coutinho, B., Netto, P., Azeredo, R., Polinski, R., and Bertolini, A. (2015). Presalt carbonate evaluation for santos basin, offshore brazil. PETROPHYSICS, 56:577.

Bronikowska, M. and Pisarska, J., L. A. (2021). Dropstone deposition: Results of numerical process modeling of deformation structures, and implications for the reconstruction of the water depth in shallow lacustrine and marine successions. Journal of Sedimentary Research, 91(5):507–519.

Gonçalves, F. (2001). Controles limnolÓgicos sobre a formaÇÃo de rochas geradoras de petrÓleo lacustres: O exemplo da bacia de camamu, nordeste do brasil félix thadeu teixeira gonÇalves. Geociências - UNESP, 20:5–23.

Hamilton, S., Munyaho, A. T., Krach, N., and Glaser, S. (2016). Lake victoria bathymetry contours, v7.

Jafelice, R., Barros, L., and Bassanezi, R. (2012). Teoria dos conjuntos fuzzy com aplicações.

Kelts, K. (1988). Environments of deposition of lacustrine petroleum source rocks: an introduction. Geological Society, London, Special Publications, 40(1):3–26.

Neves, I., Lupinacci, W., Ferreira, D., Zambrini, J., Oliveira, L., Azul, M., Ferrari, A., and Gambôa, L. (2019). Presalt reservoirs of the santos basin: Cyclicity, electrofacies, and tectonic-sedimentary evolution. Interpretation.

Scotese, C. (2013). Kt globe, paleomap project, evanston. page 3.

Siddig, O., Gamal, H., Soupios, P., and Elkatatny, S. (2021). Utilization of adaptive neuro-fuzzy interference system and functional network in prediction of total organic carbon content. SN Applied Sciences, 4.

Talbot, M. R. (1988). The origins of lacustrine oil source rocks: evidence from the lakes of tropical africa. Geological Society, London, Special Publications, 40(1):29–43.

Warner, J., Sexauer, J., alexsavio, Unnikrishnan, A., Castelão, G., Pontes, F. A., laurazh, T., Batista, F., alexbuy, den Broeck, W. V., Song, W., Pérez, R. A. M., Power, J. F., Mishra, H., Trullols, G. O., and Hörteborn, A. (2019). Scikit-fuzzy version 0.4.2.

Wright, P. and Rodriguez, K. (2018). Reinterpreting the south atlantic pre-salt 'microbialite' reservoirs: Petrographic, isotopic and seismic evidence for a shallow evaporitic lake depositional model. First Break, 36:71–77.

Obrigado!

Fale conosco

contato@achillesbr.org

victorcarreira@id.uff.br

Universidade Federal Fluminense

PETROBRAS