7
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Inter-basinal Cyclostratigraphic Correlation of Neocomian – Barremian Alam El Buieb Formation in the Northern Part of the Western Desert, Egypt

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CYCLOSTRATIGRAPHIC analysis is a successful tool for the correlation of the distant rock sections. This analysis is used in the present study to correlate of Alam EL Buieb Formation in four wells in the Western Desert of Egypt. The studied sections comprise the members of E, D, C, B and A members in Um Baraka Basin (El Noor-1X, Sallum East-1X and Zayed-1X wells) and Ghazalat Basin (WKAL C-1XST well). The power spectral analysis is used to define the periodicities of continuous G-ray log and revealed great similarities in the values and their ratios. This similarity is used to correlate the studied section based on the filtered data and smoothed filtered data. The correlation result in identification and classification of the studied sections into 20 cycles. The spectral similarity with the 405kyr metronome indicates that the orbital eccentricity controlled the deposition. The local subsidence and sedimentation rates cause only minor changes and did not interfere with cyclic changes preservation.

Keywords: Alam El Buieb Formation; Cyclostratigraphy; Western Desert; Time series analysis

1. Introduction

Alam El Buieb Formation is one of the most prominent rock units in the Western Desert and it plays an essential roles both as source and reservoir in the in the petroleum system (Makled et al., 2020). The correlation of this important rock unit throughout different basins is affected by the local elements like subsidence rates during tectonic movements as well as the differences in clastic sedimentation rates. The correlation of the rock sections are of great importance in the petroleum explorations and are needed to study the lateral extension and continuity throughout the basins (Catuneanu, 2006). Cyclostratigraphic applications provide the best tools for correlation to measure the spectral similarity between the studied sections and to eliminate the effects of sedimentation and subsidence rates. The cyclostratigraphy allow filtering the data noise and focusing on certain cycles that are used in correlations (Makled, 2021). Accordingly, the present work aims to establish the correlation between the studied sections from different basins in Western Desert of Egypt including Ghazalat and Qattatra based on cyclostratigraphic analysis of G-ray log. The Electric logs are usually used to obtain the petrographic characteristics of the rock and to evaluate their hydrocarbon potentiality as source or reservoirs (Ghorab et al., 2012; Shazly et al., 2013; El-Khardragy et al., 2018).

2 Geological settings

The studied sections are collected from four wells (Fig. 1). Three of these wells are located in Um Baraka Basin that is a part of Mamura – Matruh platform in the Northern part of the Western Desert. These wells are EL Noor-1X well (East 26.07201, North 31.3269194), Sallum East-1X (East 26.18681, North 31.333018884678) and Zayed -1X (East 26.4202778, North 31.0447222). WKAL C-1XST well (East 25.77525 North 30.4001861) is selected

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from Qattara (Fig. 1). The studied sections in the Ghazalat Basin have more or less uniform thicknesses (Table 1). The lithological composition is composed mainly of clastic rocks with dominant shale and sandstone in the lower member, shale in the middle members and dolomite in the upper member (Fig. 2). The composition and thickness changes significantly in the Qattara Basin as represented by WKAl C-1XST well and it is dominant with sandstone in all of the members (Fig. 2). The basins are separated NW-SE faults (Said, 1990; Sestini, 1995).

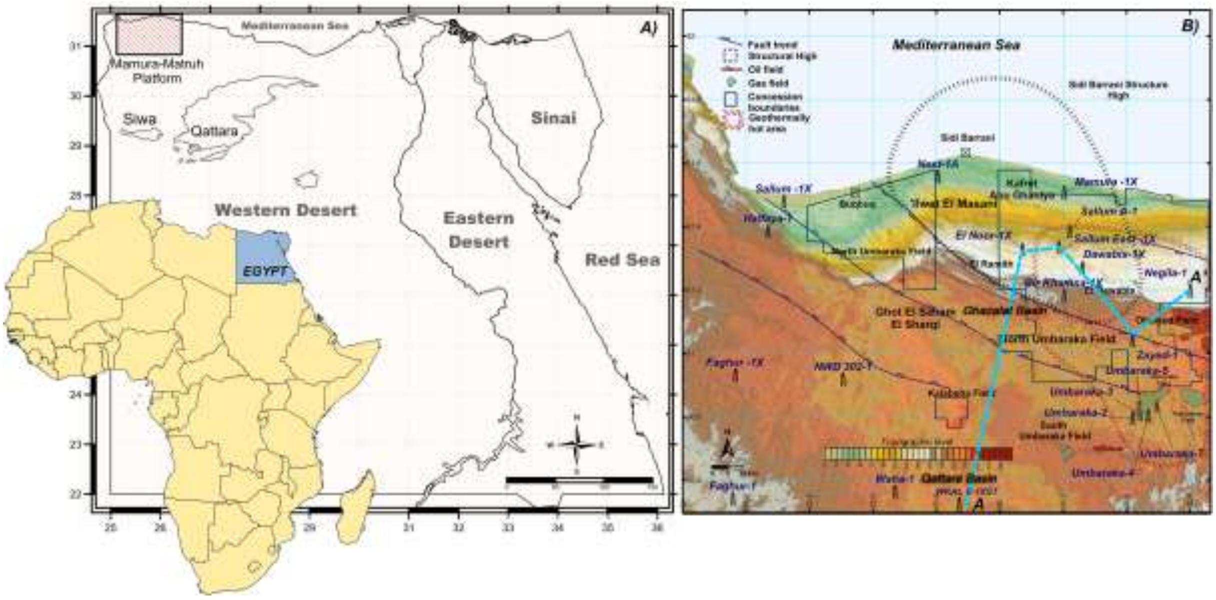

Fig. 1: Location map showing the positions of the studied wells.

Table 1: Total thickness of the studied sections, number of beds and bedding rates.

Well name	Base (ft)	Top (ft)	Thickness (ft)	Beds	Bedding rate
WKALC-1ST well	13504	9350	4154	515	0.12
El Noor-1X well	11820	9748	2072	60	0.03
Sallum East-1 well	11548	9455.3	2092.7	141	0.07
Zayed -1X well	11660	9342	2318	71	0.03

3 Material and methods

The G-ray electric logs were collected from the different well and they represent the basic time series for the analysis. The sampling range is considerably narrow in WKAl C-1XST well (0.25 feet) and El Noor-1X and Zayed well (0.5 feet) whereas it is wide in Sallum East-1X (5 feet). The power spectral analysis of the G-ray time series is established by multi-taper method (MTM), continuous wavelet transform and Fourier Wavelet Transform (Prokoph and Agterberg, 1999; Boulila et al., 2010a, b; Zhang et al., 2015, Jin et al., 2019; Boulila et al., 2020).

4 Results and discussions

4.1 G-ray periodicities across well transect in Alam El Buieb

The studied section is discriminated to different beds based on their electric characteristic obtained from well logs and several bedding planes can be identified (Fig. 2). Alam El Buieb section in the WKALC-1ST well in Qattara Basin comprises mostly successions of siliciclastic rocks (sandstone, siltstone, and shale) (Fig. 2). The section includes 515 beds with resolution 0.12 bed /foot (9350-13504 feet). In the Um Baraka Basin, the section is of uniform thickness (Sallum East-1 well, 9455.3-11548 ft), El Noor-1X well 9748-11820 ft and Zayed -1X well 9342-11660 ft). The bedding rate is lower than these in the WKALC-1ST well and ranges between 0.03 bed/foot in El Noor-1X and Zayed -1X well and 0.06 bed/foot in Sallum East well (Table 1). The thickness and bedding rate increases significantly from the Ghazalat to Qattara Basin. Despite the changes similar lithostratigraphic similarity can be traced through put the basins in addition to observable stratified cycles or sequences. Makled et al. (2020) classified the rhythmic bedding into and palynofacies into eight sequences E4, E3, E2, E1, D1, C1, C2 and B1. However, additional cycles can be detected based on the cyclostratigraphic methods by spectral analysis.

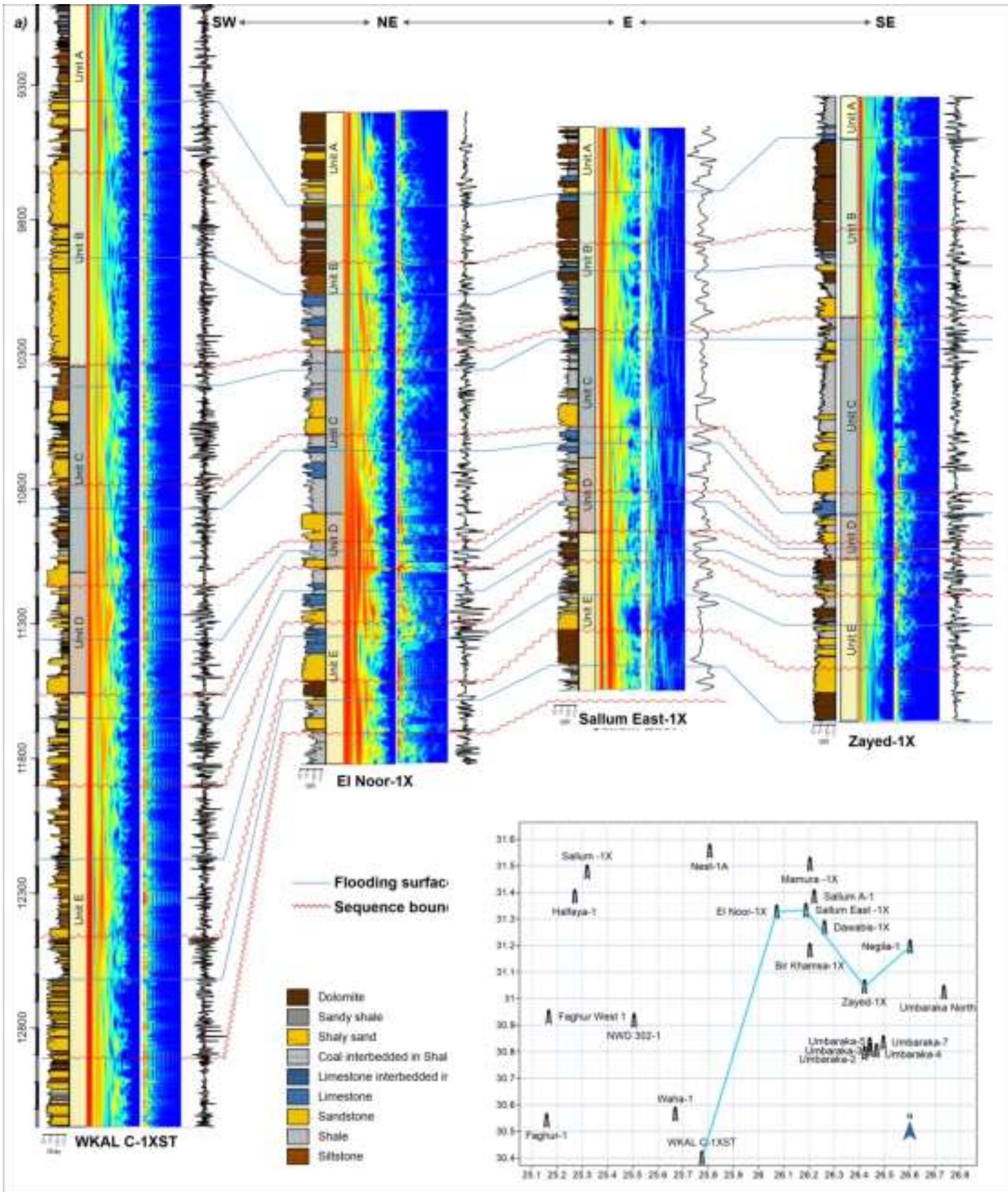

Fig. 2. Continuous Wavelet transform and Fourier wavelet transform correlation of the studied well sections. Sequence boundaries of Makled et al. (2020) are presented. The filtered G-ray is presented.

The G-ray electric log has continues record throughout the studied wells (Fig. 2). Using of different kinds of the spectral analysis that fit with the digitized methods and sample points lead to some variation in the calculated wavelengths (Fig. 3). In WKALC-1ST well in Qattara Basin, the peak periodicities range between long 4545 and short 524 feet (18044 sample count, Table 2). In Um Baraka Basin, the peak periodicities in El Noor -1X (4841 sample, 4482.5- 219.2ft), Zayed-1X (4638 samples, 3797.3-358.0 ft) wells have more or less equal periodicities to these of WKALC-1ST well (Table 2). Sallum East-1 well has different range of periodicities (573.5-25.3 ft) because of lower sample number and longer sample interval (791 samples) (Table 2). The periodicities resulted from the spectral analysis are converted to ratios to be correlated across different wells (Makled, 2021). The periodicities ratios reveal large similarities throughout the studied wells indicating that one changing in same rhythmic regularity (Table 2). The larger similarity occurs between El Noor-1X and Sallum East -1 well throughout the spectrum of the periodicities (Table 2).

Larger ratio similarities occur when long periodicities are compared to the other short periodicities including 2.3, 3.2, 5.1, 6.2, 7.9, 12.0, 13.1, 15.3, 16.2 and 19.5 (Table 2). The ratios are also correlatable in the same long periodicities of Zayed -1X (2.8, 4.0 and 5.8) (Table 2). The similarities with WKALC-1ST well are detected from long to short including 3.2, 5.2, 6.4 and 7.2 (Table 2).

The large similarities in the ratio distribution of long and short ratios are also detected in by Short Time Fourier transform and wavelet transforms (Fig. 2). The analysis using these methods, however, is not affected by short problematic obliquity. The Fourier transform is based on a window of 64 feet wide and is useful to identify unconformities at the changing levels of frequency as a response of changing in sedimentation rate in the scalogram (Fig. 2). The G-ray is also filtered using bandpass to remove unwanted cycles based on the coefficients determined in the power spectral analysis (Fig. 2). The filtered data are then smoothed by Gaussian function (Fig. 4). The filtered and smoothed data products are used to identify cycles in the studied sections and in correlation throughout the basins.

4.2 Cyclic changes in studied section

Based on the spectral analysis of the G-ray from the studied section, 20 cycles can be identified using the cyclostratigraphic similarity (Fig. 3). The identified cycles can be traced through EL Noor-1, Sallum East -1X and Zayed-1X and to lesser degree to the WKAL C-1XST well (Fig. 3). The continuity of the cycles may be interrupted laterally and recognition and classification of the cycles can be difficult. To overcome this interruption, different width of bandpass is used to achieve best correlation lines between the wells. However, the preservation of the cycles is not homogenous everywhere and the local tectonic elements would results in some differences (Fig. 3).

The differences in the rate of the subsidence as well as the differences in the clastic sedimentation rates can over write the cycle. The main discrepancies occur when the cycle boundary is correlated to maximum in one cycle and to maximum in the correlated cycle. However, these differences did not prevent the identification of the cycles in the studied section with optimum certainty. The cycles are found to cross the Member boundaries (Fig. 3). They are also refines the sequence boundaries identified in Makled et al. (2020).

Based on the comparison with the 405kyr ratios, there is a large similarity in the periodicity ratios including 2.7, 4.9 and 16.2 (Table 2). This indicates that the deposition in Qattara and Ghazalat basin was in Alam EL Buieb Formation is subjected to the astronomical position (eccentricity). The possibility to correlate the cycles throughout the basin signifies the minor impact of tectonics elements and clastic input cycle preservation.

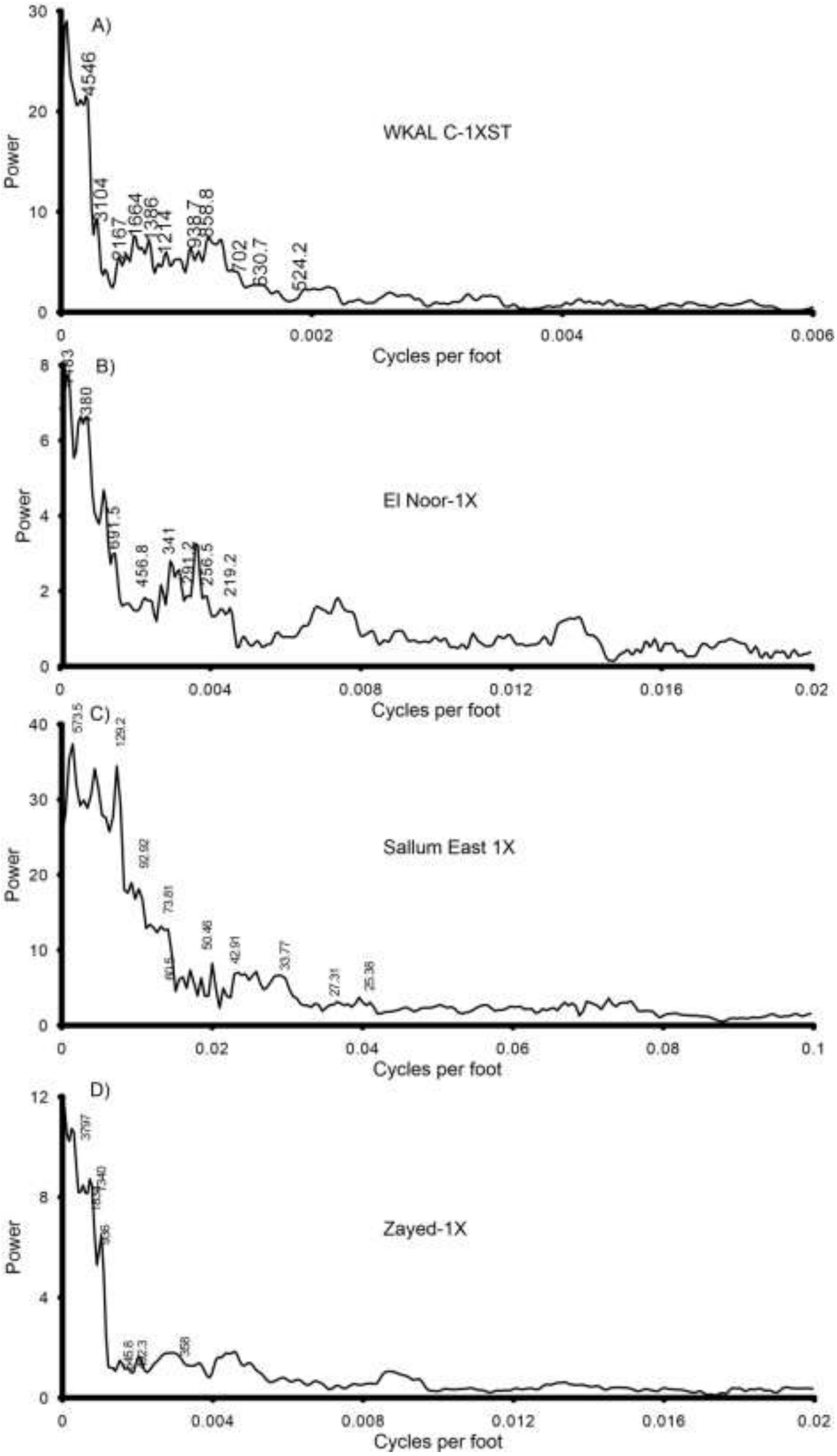

Fig. 3. MTM power spectra results from the time series analysis of the studied wells based on G-ray logs.

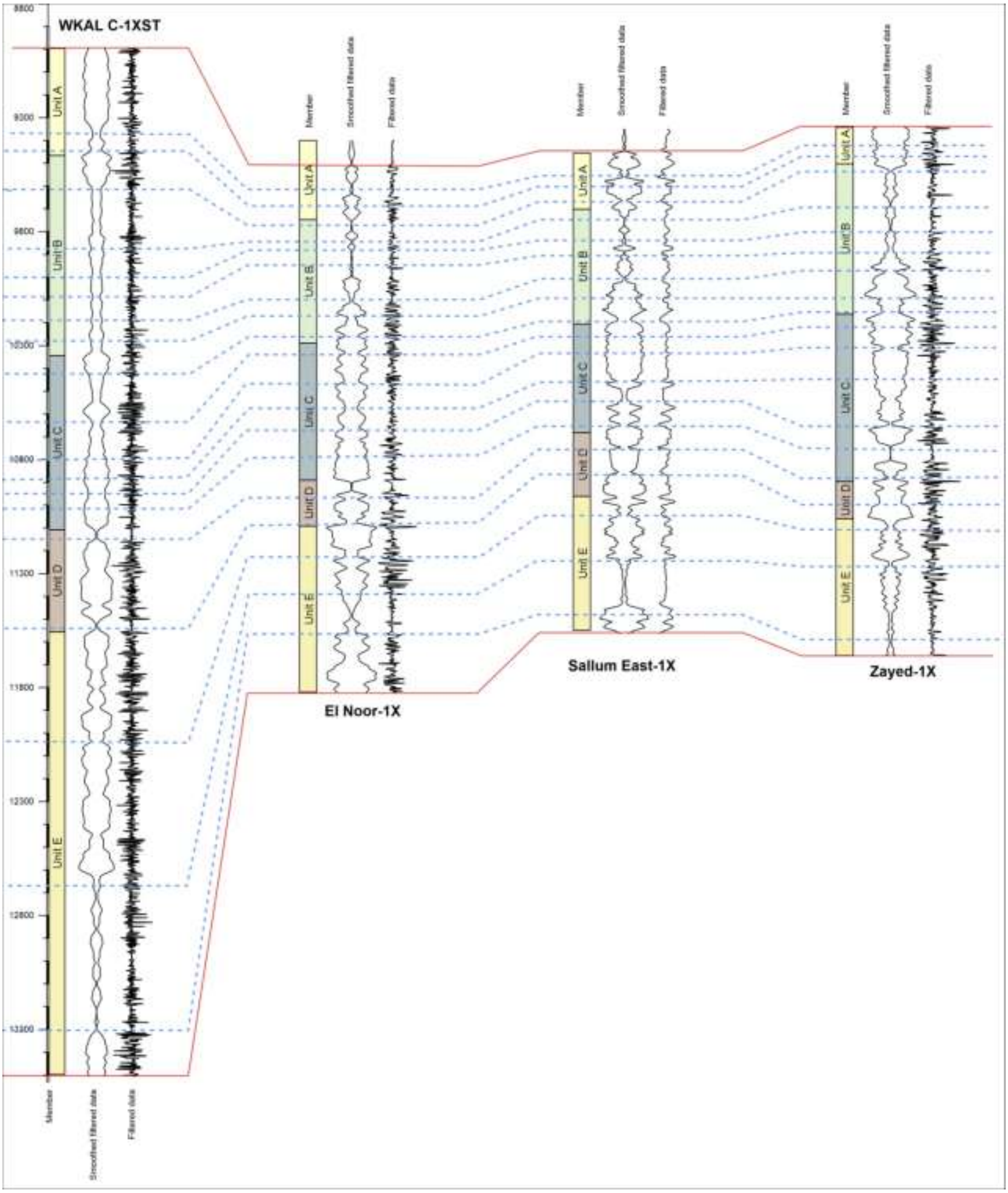

Fig. 4. Identified cycles and their lateral correlation throughout the Ghazalat and Qattara Basins.

Table 2. Ratio table of the periodogram lengths in feet that are determined from the time series analysis. The same colours identifies the similar ratios.

WKALC-1ST well

	4545.6	3103.9	2166.8	1664.3	1385.8	1213.9	938.7	858.8	702.0	630.7	524.2
4545.6	1.0										
3103.9	1.5	1.0									
2166.8	2.1	1.4	1.0								
1664.3	2.7	1.9	1.3	1.0							
1385.8	3.3	2.2	1.6	1.2	1.0						
1213.9	3.7	2.6	1.8	1.4	1.1	1.0					
938.7	4.8	3.3	2.3	1.8	1.5	1.3	1.0				
858.8	5.3	3.6	2.5	1.9	1.6	1.4	1.1	1.0			
702.0	6.5	4.4	3.1	2.4	2.0	1.7	1.3	1.2	1.0		
630.7	7.2	4.9	3.4	2.6	2.2	1.9	1.5	1.4	1.1	1.0	
524.2	8.7	5.9	4.1	3.2	2.6	2.3	1.8	1.6	1.3	1.2	1.0

El Noor-1X well

	4482.5	1910.4	1379.9	858.8	691.5	565.5	456.8	371.6	341.0	312.9	291.2	275.1	256.5	231.5	219.2
4482.5	1.0														
1910.4	2.3	1.0													
1379.9	3.2	1.4	1.0												
858.8	5.2	2.2	1.6	1.0											
691.5	6.5	2.8	2.0	1.2	1.0										
565.5	7.9	3.4	2.4	1.5	1.2	1.0									
456.8	9.8	4.2	3.0	1.9	1.5	1.2	1.0								
371.6	12.1	5.1	3.7	2.3	1.9	1.5	1.2	1.0							
341.0	13.1	5.6	4.0	2.5	2.0	1.7	1.3	1.1	1.0						
312.9	14.3	6.1	4.4	2.7	2.2	1.8	1.5	1.2	1.1	1.0					
291.2	15.4	6.6	4.7	2.9	2.4	1.9	1.6	1.3	1.2	1.1	1.0				
275.1	16.3	6.9	5.0	3.1	2.5	2.1	1.7	1.4	1.2	1.1	1.1	1.0			
256.5	17.5	7.4	5.4	3.3	2.7	2.2	1.8	1.4	1.3	1.2	1.1	1.1	1.0		
231.5	19.4	8.3	6.0	3.7	3.0	2.4	2.0	1.6	1.5	1.4	1.3	1.2	1.1	1.0	
219.2	20.4	8.7	6.3	3.9	3.2	2.6	2.1	1.7	1.6	1.4	1.3	1.3	1.2	1.1	1.0

	Sallum East-1 well																	
	573.5	234.8	129.2	110.9	92.9	83.1	73.8	63.3	60.5	53.9	50.5	45.3	42.9	38.0	33.8	29.3	27.3	25.4
573.5	1.0																	
234.8	2.4	1.0																
129.2	4.4	1.8	1.0															
110.9	5.2	2.1	1.2	1.0														
92.9	6.2	2.5	1.4	1.2	1.0													
83.1	6.9	2.8	1.6	1.3	1.1	1.0												
73.8	7.8	3.2	1.7	1.5	1.3	1.1	1.0											
63.3	9.1	3.7	2.0	1.8	1.5	1.3	1.2	1.0										
60.5	9.5	3.9	2.1	1.8	1.5	1.4	1.2	1.0	1.0									
53.9	10.6	4.4	2.4	2.1	1.7	1.5	1.4	1.2	1.1	1.0								
50.5	11.4	4.7	2.6	2.2	1.8	1.6	1.5	1.3	1.2	1.1	1.0							
45.3	12.7	5.2	2.8	2.4	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0						
42.9	13.4	5.5	3.0	2.6	2.2	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0					
38.0	15.1	6.2	3.4	2.9	2.4	2.2	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.0				
33.8	17.0	7.0	3.8	3.3	2.8	2.5	2.2	1.9	1.8	1.6	1.5	1.3	1.3	1.1	1.0			
29.3	19.6	8.0	4.4	3.8	3.2	2.8	2.5	2.2	2.1	1.8	1.7	1.5	1.5	1.3	1.2	1.0		
27.3	21.0	8.6	4.7	4.1	3.4	3.0	2.7	2.3	2.2	2.0	1.8	1.7	1.6	1.4	1.2	1.1	1.0	
25.4	22.6	9.3	5.1	4.4	3.7	3.3	2.9	2.5	2.4	2.1	2.0	1.8	1.7	1.5	1.3	1.2	1.1	1.0

	Zayed -1X well						
	3797.3	1834.5	1339.8	936.0	645.8	492.3	358.0
3797.3	1.0						
1834.5	2.1	1.0					
1339.8	2.8	1.4	1.0				
936.0	4.1	2.0	1.4	1.0			
645.8	5.9	2.8	2.1	1.4	1.0		
492.3	7.7	3.7	2.7	1.9	1.3	1.0	
358.0	10.6	5.1	3.7	2.6	1.8	1.4	1.0

	Orbital forcing cycles							
	405.4	180.0	146.5	82.1	26.4	25.0	19.9	19.0
405.4	1.0							
180.0	2.3	1.0						
146.5	2.8	1.2	1.0					
82.1	4.9	2.2	1.8	1.0				
26.4	15.4	6.8	5.5	3.1	1.0			
25.0	16.2	7.2	5.9	3.3	1.1	1.0		
19.9	20.4	9.0	7.4	4.1	1.3	1.3	1.0	
19.0	21.3	9.4	7.7	4.3	1.4	1.3	1.0	1.0

Conclusions

The studied sections of Alam El Buieb Formation comprise the members E, D, C, B and A and they are well correlated based on the cyclostratigraphic application of power spectral analysis o G-ray electric log. The correlation facilitates the determination of the depositional similarities in both Um Baraka and Ghazalat Basins. There are large spectral similarities between the studied section from Um Baraka Basin including EL Noor-1X, Sallum East-1X and Zayed -1X and the WKAL C-1XST in Ghazalat Basin. The similarities are found in periodicities and their ratios. The filtered and smoothed data are used to identify 20 cycles in the studied section with minor differences that resulted from differences in subsidence and sedimentation rates. However, they are minor differences and allowed identification of the cycles throughout the wells with optimum certainty.

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References

Boulila, S., Brange, C., Cruz, A.M., Laskar, J., Gorini, C., Reis, T.D., Silva, C.G., 2020. Astronomical pacing of Late Cretaceous third- and second-order sea-level sequences in the Foz do Amazonas Basin. Mar. Petrol. Geol. 117, 104382. https://doi.org/ 10.1016/j.marpetgeo.2020.104382.

Boulila, S., de Raf´elis, M., Hinnov, L.A., Gardin, S., Galbrun, B., Collin, P.-Y., 2010b. Orbitally forced climate and sea-level changes in the Paleoceanic Tethyan domain (marl-limestone alternations, Lower Kimmeridgian, SE France). Palaeogeogr. Palaeoclimatol. Palaeoecol. 292, 57–70.

Boulila, S., Galbrun, B., Hinnov, L.A., Collin, P.-Y., Ogg, J.G., Fortwengler, D., Marchand, D., 2010a. Milankovitch and sub-milankovitch forcing of the Oxfordian (late Jurassic) Terres Noires formation (SE France) and global implications. Basin Res. 22, 717–732.

Catuneanu, O., 2006. Principles of Sequence Stratigraphy. Elsevier, Amsterdam, 375 pp.

El Khadragy, A.A., Shazly, T.F., Mousa, D., A., Ramadan, M., El Sawy, M. Z., 2018. Integration of well log analysis data with geochemical data to evaluate possible source rock. Case study from GM-ALEF-1well, Ras Ghara oil Field, Gulf of Suez, Egypt. Egyptian Journal of Petroleum, 27(4), 911-918.

Ghorab, M., Shazly, T. F., Ghaleb, I. E., Nabih, I., 2012. Using f Pickett's plot in shaly formatin to estimate the petrophysical exponents of Bahariya Formation in Sidi Barani Area, North Western Desert, Egypt. Australian journal of Basic and Applied Science, 6(13), 399-413.

Jin, S., Cao, H., Wang, H., Wagreich, M., Richoz, S., 2019. Orbital cyclicity in sedimentary sequence and climatic indications of C-O isotopes from lower cretaceous in Qingxi Sag, Jiuquan basin, NW China. Geoscience Frontiers 10, 467–479.

Makled, W.A., Abd El Moneim, A., Mostafa, T.F., El Sawy, M.Z., Mousa, D.A., Ragab, M. O., 2020. Petroleum play of the lower cretaceous Alam El Bueib Formation in the El Noor-1X well in the north Western Desert (Egypt): a sequence stratigraphic framework. Mar. Petrol. Geol. 116, 104287. https://doi.org/10.1016/j. marpetgeo.2020.104287.

Makled, W.A., Gentzis, T., Hosny, A.M., Mousa, D.A., Lotfy, M.M., Abd El Ghany, A.A., El Sawy, M.Z., Orabi, A.A., Abdelrazak, H.A., Shahat, W.I., 2021. Depositional dynamics of the Devonian rocks and their influence on the distribution patterns of liptinite in the Sifa-1X well, Western Desert, Egypt: implications for hydrocarbon generation. Mar. Petrol. Geol. 126, 104935. .

Prokoph, A., Agterberg, F.P., 1999. Detection of sedimentary cyclicity and stratigraphic completeness by wavelet analysis: application to Late Albian cyclostratigraphy of the Western Canada Sedimentary Basin. J. Sediment. Res. 69, 862–875.

Said, R., 1990. The Geology of Egypt. A. Balkema Publishers, USA, pp. 734.

Sestini, G., 1995. Egypt. In: Kulke, H. (Ed.), Regional Petroleum Geology of The World, Part II: Africa, America, Australia and Antarctica (Beitrage zur regionalen Geologie der Erde 22. Gebruder Borntraeger Verlagsbuchhandlung, Stuttgart, pp. 66–87.

Shazly, T.F., Ramadan, M., El Sawy, M.Z., 2013. Application of well logs analysi to identify the source rock capabilities of Rudeis and Kareem Formation in Rudeis Field, Gulf of Suez, Egypt. Journal of Applied Science Research, 9(9), 5419-5435.

Zhang, Y., Li, M., Ogg, J.G., Montgomery, P., Huang, C., Chen, Z.-Q., Shi, Z., Enos, P., Lehrmann, D.J., 2015. Cycle-calibrated magnetostratigraphy of middle carnian from South China: implications for late Triassic time scale and termination of the Yangtze Platform. Palaeogeogr. Palaeoclimatol. Palaeoecol. 436, 135–166.

الارتباط السيكلوستراتجرافي بين الحوضي لمتكون علم البويب النيوكومي –البارمي في شمال الصحراء الغربية مصر

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يعتبر التحليل السيكلوستراتجرافي أداة ناجحة لربط الأجزاء الصخرية البعيدة ويتم استخدامه في هذه الدراسة لربط تكوين علم البويب في اربع ابار في الصحرا الغربية بمصر. تضم الأقسام المدروسة أعضاء E وD وC وB وA في حوض أم بركة (آبار النور –X١، والسلوم الشرقي –X١، وزايد X١) وحوض الغزالات (بئر WKAL C-1XST). يستخدم التحليل الطيفي لتحديد التواتر الدوري سجل G-ray المستمر الذي كشف عن أوجه تشابه كبيرة في القيم ونسبها. يستخدم هذا التشابه لربط القسم المدروس بناءً على البيانات المصفاة والبيانات المصفاة المصقولة. نتج عن الارتباط تحديد وتصنيف الأقسام المدروسة إلى ٢٠ دورة. يشير التشابه الطيفي مع المسرع kyr٤٠٥ إلى أن الانحراف المداري تحكم في عمليات الترسيب. تسبب معدلات الهبوط والترسيب المحلية تغييرات طفيفة فقط ولم تتداخل مع الحفاظ على التغييرات الدورية.