An Updated Chronostratigraphic Framework for the Jurassic of the Arabian Platform: Towards a Regional Stratigraphic Standard*

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Abstract

The past few decades the focus of hydrocarbon exploration and production in the Middle East progressively has moved to deeper/older plays. In fact, the Jurassic succession of the Arabian Platform is now among the major hydrocarbon-producing intervals of the Middle East. On this platform, widespread carbonate deposition resulted in a vertical and lateral mosaic of shallow-water facies adjacent to deeper water coarser-grained deposits. An improved high-resolution sequence stratigraphic framework is crucial for building highly resolved geological models for reservoir distribution and characterization. Currently, there is a good understanding of the structural features of the Jurassic in the region, primarily based on sedimentology and seismic mapping (Yousif and Nouman, 1995, 1997; Haq and Al-Qahtani, 2005, Figure 1). However, in order to start understanding the genesis and sequence stratigraphic position of Jurassic plays, a firm chronostratigraphic framework is essential. Unfortunately, the application of a single, routinely used biostratigraphic tool appears problematic in the generally carbonate-rich and oil-saturated depositional systems of the Jurassic of the Arabian Platform. Here we present the results of a multidisciplinary study performed with the aim of constructing a chronostratigraphic framework for the Jurassic of West Kuwait, an area that hosts an important Jurassic hydrocarbon play.

Methodology

We have studied material from thirteen cored sections and two sets of drill-cuttings from West Kuwait. Biostratigraphic correlations were established by generating and integrating over 650 analyses focusing on organic microfossils (palynology, particularly dinoflagellate cysts), foraminifera, calcareous nannofossils and macrofossils. Furthermore, we have employed stable isotope techniques in order to test and refine the ensuing correlations. Here we present the stable carbon isotopes that were derived from carbonate ($\delta^{13}C_{CARB}$). The stable carbon isotopic composition recorded in (marine) carbonates and organic material is controlled by the distribution of the stable isotopes among different carbon-reservoirs. This property makes it a valuable tool for supra-regional correlation. Furthermore, it can be performed on very high resolution, providing additional detail compared to biostratigraphy. In total 695 samples were analyzed for $\delta^{13}C_{CARB}$, 83 of which concern drill-cuttings with the purpose of covering intervals for which cored material was not available. Next to that, Strontium (Sr) isotope-analyses were also employed. Sr-isotope stratigraphy relies on the fact that the ratio between two different isotopes of Sr in the oceans has varied through time. This makes it an additional tool to independently date sediments.

Results and Discussion

Through integration of calcareous nannofossils, palynology and Sr-isotope data, we have successfully assigned robust age constrains to the different lithological units used in Kuwait (Figure 2). In some cases, the $\delta^{13}C_{CARB}$ data appeared crucial for correlation to the geological time-scale and/or the identification of discontinuity.

The oldest sediments that were studied are derived from Minjur Fm. Palynological associations indicate a Late Triassic age. Sediments from the Lower Marrat Fm. (Units D-E, Figure 2) were exclusively recovered in the cuttings. The palynological associations are dominated by sporomorphs and corroborate an Early Jurassic age. In the basal part of Unit C of the Middle Marrat Fm., we recorded a distinct $\delta^{13}C_{CARB}$ that likely corresponds to the "Early Toarcian Isotope Event" (see e.g., Hesselbo et al., 2007). As such, the underlying Lower Marrat Fm. is thought to be of Sinemurian-Pliensbachian age. Cored sections from the upper part of the Unit C of the Marrat Fm. do not yield rich palynological associations. Generally, only sporomorphs are recorded in abundance. Calcareous nannofossils are not preserved either. Strontium isotope data place the interval between the Early Bajocian and the LateToarcian. For the Upper Marrat Fm., only cuttings were sampled that did not yield useful palynological or micropaleontological information. The carbon isotopes from cuttings delineate a slight negative trend, starting at maximum values in the Middle Marrat Fm. (Unit C). In a globally stacked isotope dataset, a similar trend is recorded in the Late Aalenian to Early Bajocian (Dera et al., 2011), providing a first-order correlation.

The cored section from the Dhruma Fm. yields well-preserved palynomorphs (Figure 3) and calcareous nannofossils. These indicate a well-constrained Early-Late Bajocian age (Figure 2). The dinocyst assemblages contain taxa that are widely known to the boreal realm and therefore may indicate cooling of the surface waters. This is also consistent with oxygen-isotope derived information of cooling in the Bajocian (Dera et al., 2011).

The Sargelu Fm. is now also accurately dated using biostratigraphy. Calcareous nannofossils suggest a Late Bajocian to Early Callovian age. Dinocyst associations suggest a Middle Bathonian age for the upper part of the Sargelu Fm. In several wells, we have recorded a characteristic, non-truncated negative carbon isotope excursion (Figure 4). This suggests that there is no major unconformity across the transition between the Sargelu and Najmah Formations. Based on calcareous nannofossils, the overlying Lower Najmah Fm. is of Late Bathonian to Early Callovian age, in agreement with the strontium isotope record (Figure 2). In a sample that is taken just below the evaporites of the Gotnia Fm., the calcareous nannofossil and dinoflagellate cyst assemblages contain taxa that are widely known to occur in the Late Jurassic (Oxfordian-Kimmeridgian). This occurs within the Upper Najmah ('Shale') Fm. Strontium-isotope data place this interval in the Late Callovian to Middle Kimmeridgian. Furthermore, we record a truncation in the carbon isotope record (Figure 4). By combining these records we infer a substantial unconformity between the Upper and Lower Najmah Fm. (Early Callovian – Middle Oxfordian or younger, Figure 2). Calcareous nannofossils and dinoflagellate cysts from cored sections from the Makhul Fm., a clay-rich unit overlying the evaporates of the Gotnia an Hith Fm. yield a definite Late Jurassic age.

Conclusions

As illustrated above, the combination of these methods enables firm and internally consistent dating for the different lithostratigraphic units of the Jurassic of West Kuwait. Furthermore, the $\delta^{13}C_{CARB}$ analyses yield consistent values and trends between the different wells. These distinctly consistent isotopic patterns provide a very meaningful tool for regional correlation across the Arabian Platform, with potential for tying strata further afield to the geological timescale. Altogether, this new stratigraphic framework provides the backbone for ensuing sequence stratigraphic studies in the area. Such efforts are pivotal for obtaining an understanding of source, reservoir and cap-rock genesis on the Arabian Platform.

References Cited

Dera, G., B. Brigaud, F. Monna, R. Laffont, E., Puceat, J-F. Deconinck, P. Pellenard, M.M. Joachimski, and C. Durlet, 2011, Climatic ups and downs in a disturbed Jurassic world: Geology, v. 39, p. 215-218.

Gradstein, F., M.D. Schmitz, and G.M. Ogg, 2012, The geologic timescale 2012: Elsevier, Amsterdam, 1129 p.

Haq, B.U., and A.M. Al-Qahtani, 2005, Phanerozoic sea-level change on the Arabian Platform: GeoArabia. v. 10, p. 127-160.

Hesselbo, S.P., H.C. Jenkyns, L.V. Duarte, and L.C.V. Oliveira, 2007, Carbon-isotope record of the Early Jurassic (Toarcian) Oceanic Anoxic Event from fossil wood and marine carbonate (Lusitanian Basin, Portugal): Earth Planetary Science Letters, v. 253, p. 455-470.

Yousif, S., and G. Nouman, 1995, Geological model of the Jurassic Section in the State of Kuwait: Middle East Oil Show, DOI: 10.2118/29796-MS.

Yousif, S., and G. Nouman, 1997, Jurassic Geology of Kuwait: GeoArabia, v. 2, p. 91-110.

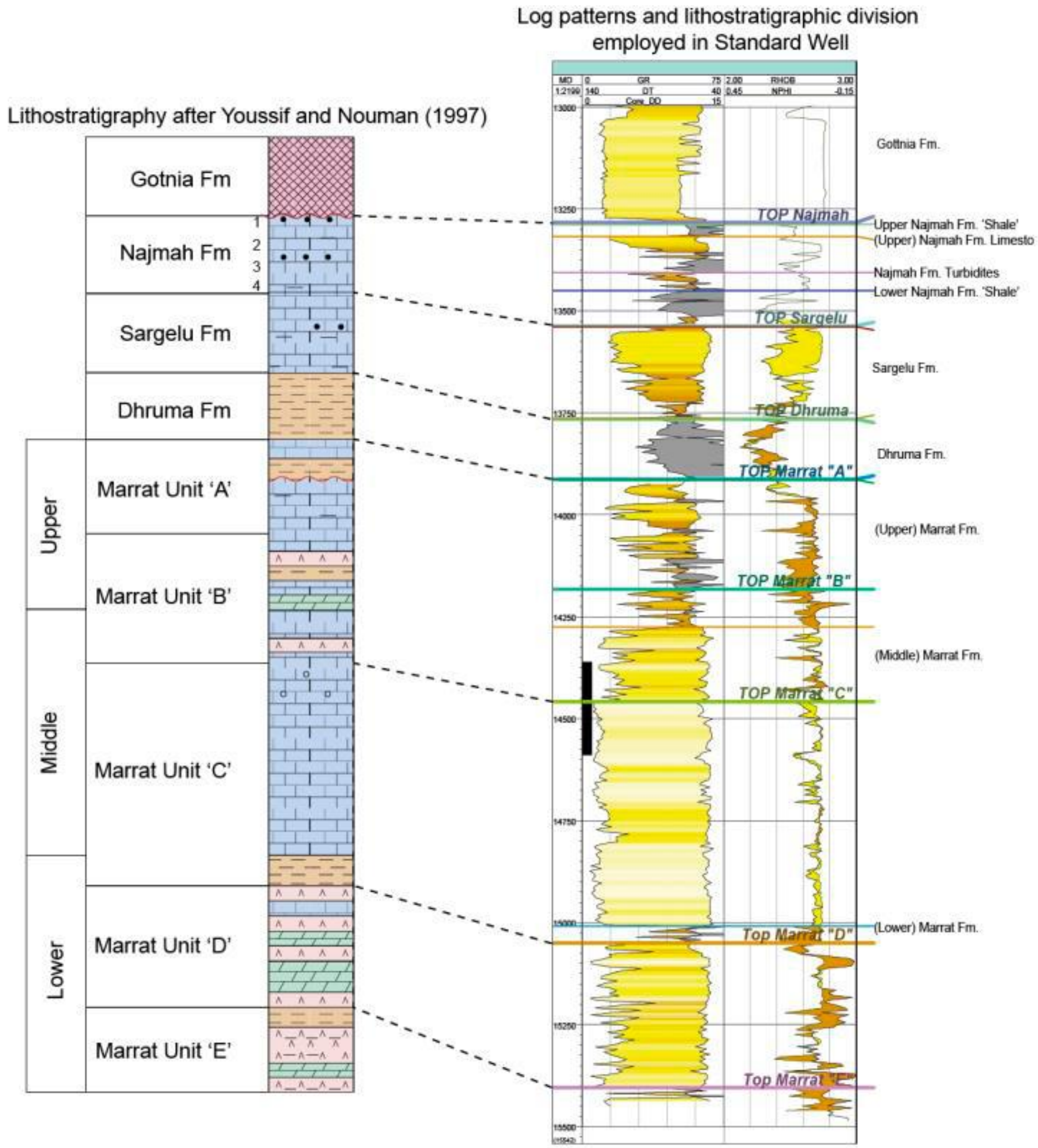

Figure 1. Relationship between the lithostratigraphic scheme of Yousif and Nouman (1997) and the lithostratigraphy employed in the present study. The gamma- (GR), sonic- (DT), density- (RHOB) and neutron porosity- (NPHI) -logs are used for correlation. The horizontal lines delineate tops of units and formations. This scheme particularly deviates from Yousif and Nouman (1997) in the Najmah Fm.

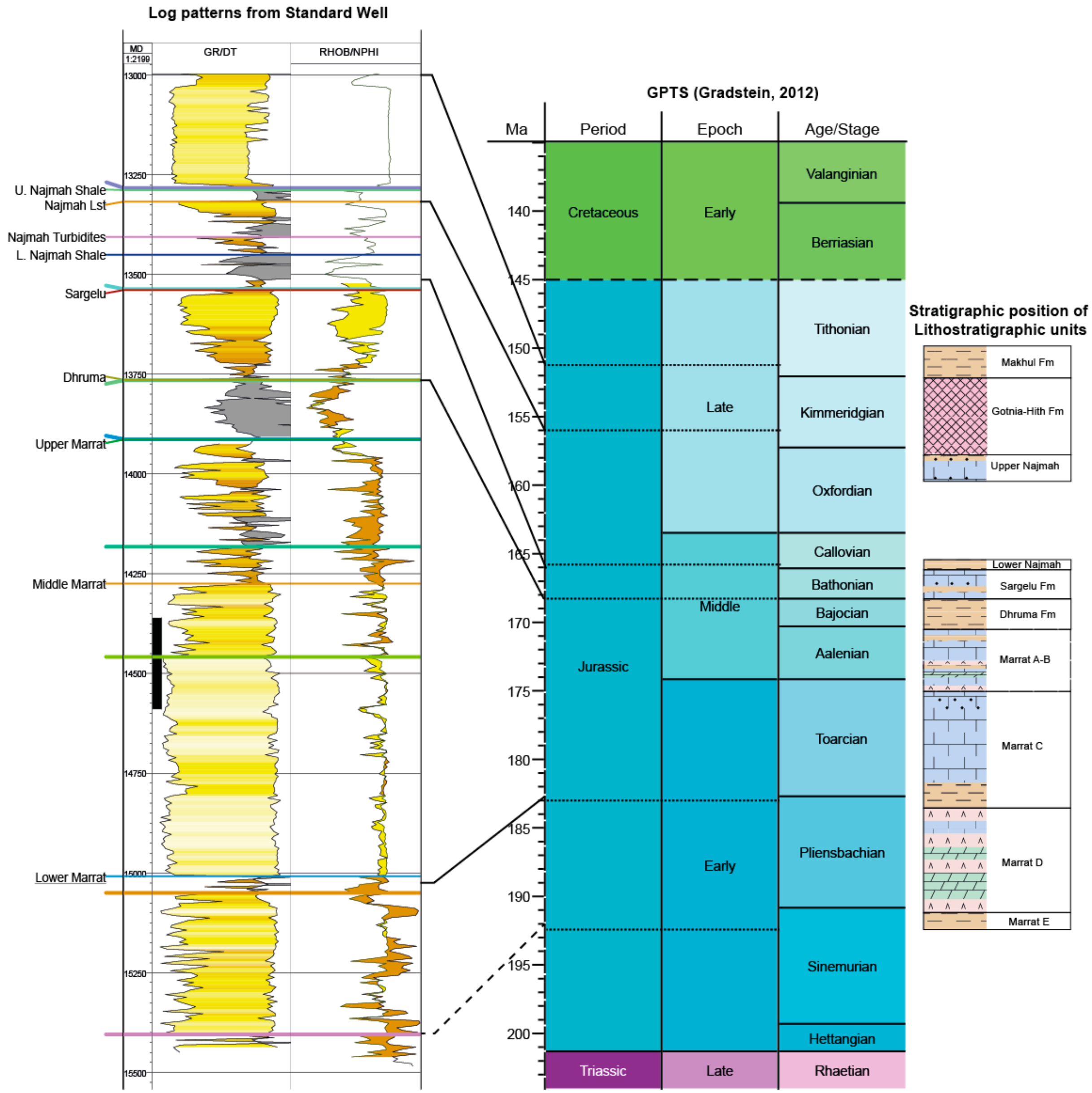

Figure 2. Ages for the lithological units from Kuwait and their log-response. The time-scale is that of Gradstein et al. (2012). The lithostratigraphy after Yousif and Nouman (1997) is also given against this time-scale at the rightmost of the figure.

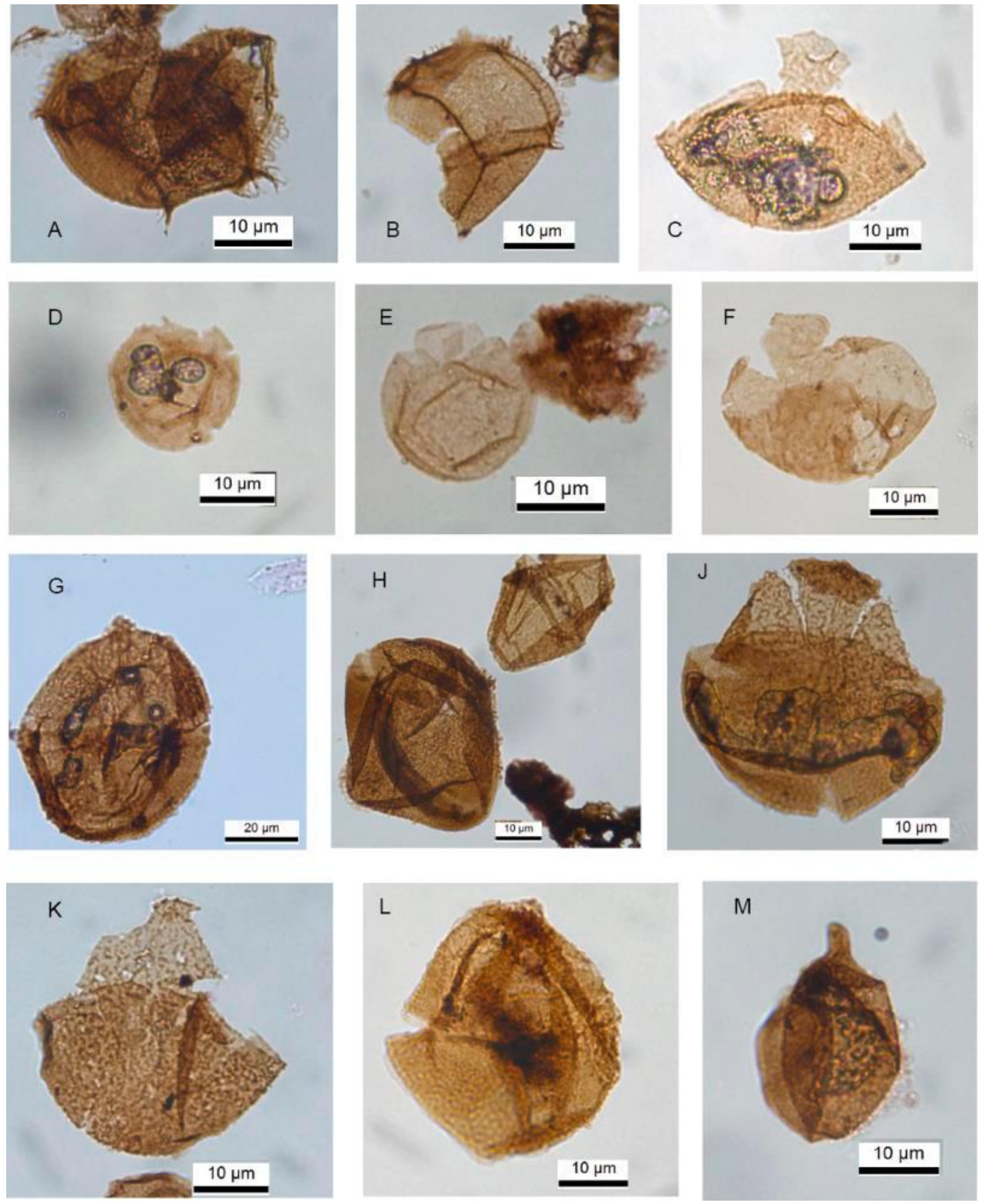

Figure 3. Characteristic dinoflagellate cysts from the Dhruma Fm.: A-B: *Ctenidodinium stauromatos*/*Dichadogonyaulax sellwoodii plexus*, C-F; *Dissiliodinium spp*., G: *Durotrigia daveyi*, H-L: *Durotrigia omentifera*, M: *Evansia evittii*.

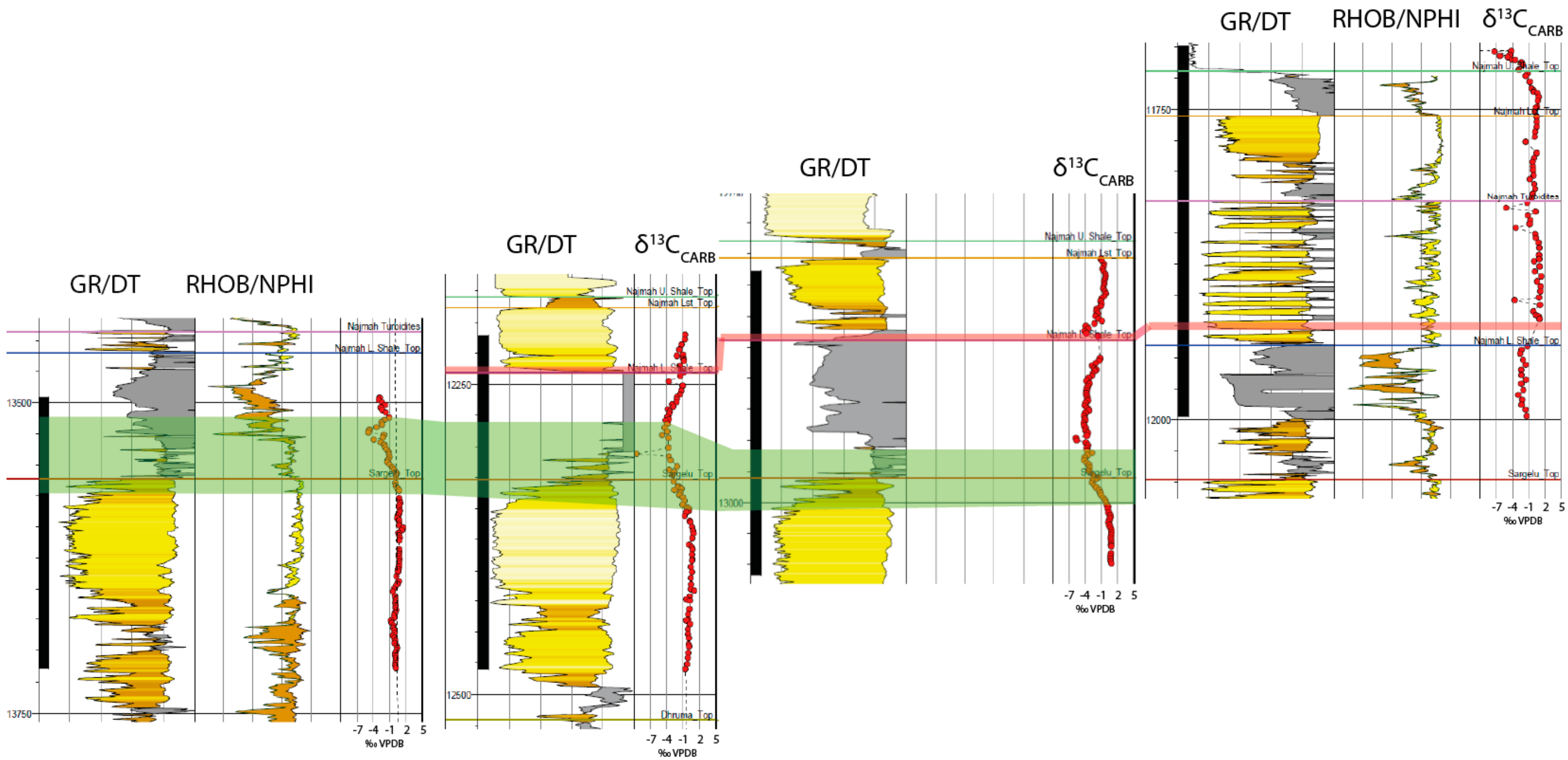

Figure 4. $\delta^{13}C_{CARB}$ records of the Najmah-Sargelu transition in four wells from West Kuwait. The lithostratigraphy follows that outline in Figure 1. The green translucent shading delineates the negative excursion across the Sargelu-Lower Najmah transition. The red translucent shading indicates truncation of the record between the Lower and Upper Najmah Fm.