

ARABIAN ORBITAL SCALE - AROS 2022

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INTRODUCTION

Most formations, members and transgressive-regressive (T-R) depositional sequences in Saudi Arabia and neighboring countries are bounded by sequence boundaries (SB), and therefore represent chronostratigraphic units. Identifying the boundaries of the international chronostratigraphic stages within these units, however, is generally not possible because age-indicative fossils are very rare and limited to just a few formations. Because of these limitations it has not been possible to date most of Arabian Plate units according to the international Geological Time Scale (e.g., GTS 2020, Gradstein et al., 2020).

To address this problem, [Matthews and Al-Husseini \(2010\)](#) formulated the Orbital Scale of glacio-eustasy consisting of c. 0.405 Myr stratons, 4.86 Myr dozons, and 14.58 Myr orbitons (see Introduction at Home of www.orbitalscale.com). Determining which Arabian Plate unit corresponds to which orbital unit is an ongoing work-in-progress. Figure 1 summarizes the results of several open-access case studies indicating the current correlation between Cretaceous-Jurassic units and the Orbital Scale.

ARUMA FORMATION

In the outcrops of Saudi Arabia, the Aruma Formation consists of the Paleocene Lina Member and Late Cretaceous Hajajah and Khanaser Members (see review and orbital calibration in [Al-Husseini, 2021a](#)). The Cretaceous/Paleocene (KT) Boundary occurs between the Lina and Hajajah members, but the stage assignment of the Lina Member to the Danian, Thanetian and/or Selandian stages is unresolved by biostratigraphy. Also, the position of the Campanian/Maastrichtian Boundary in the Hajajah or Khanaser members is not resolved by biostratigraphy.

The Hajajah Member may be exclusively Maastrichtian, in which case it would consist of candidate Stratons 179 to 164 (72.461–65.981 Ma). The lower part of the Khanaser Member is dated by biostratigraphy as late Campanian and so its base may correspond to SB 5 at 74.486 Ma. The pre-Aruma Unconformity at outcrop represents a Turonian to late Campanian hiatus, and is also referred to as the Turonian Unconformity. The Hajajah Member is correlated to the Simsima Formation in Oman, in which its stratons are somewhat better resolved.

NATIH FORMATION

The Turonian Unconformity in Oman occurs at the top of the Natih Formation, and the formation consists from base-up of seven members named G to A. The members can be approximately dated based on biostratigraphy and carbon-isotope ($\delta^{13}\text{C}$) correlations to the English Chalk (see review and orbital calibration in [Al-Husseini, 2021b](#)).

The Natih A Member is calibrated by the five Stratons 234 to 230 (94.736–92.711 Ma). The Cenomanian/Turonian Boundary occurs below Straton 232 at 93.926 Ma (93.9 ± 0.2 Ma in GTS 2020). It corresponds to SB 7C and the maximum value in the positive $\delta^{13}\text{C}$ excursion CTBE. This calibration was used to date the Turonian Unconformity at 92.711 Ma, near the Early/Middle Turonian Boundary in GTS 2020.

The Natih B Member is calibrated by Stratons 237 to 235 (95.951–94.736 Ma), the Natih C Member by Straton 238 (96.356–95.951 Ma), and the Natih D Member by Straton 239 (96.761–96.356 Ma). The Natih E Members is calibrated by Stratons 248 to 240 (100.406–96.761 Ma) and the Albion/Cenomanian Boundary occurs at the maximum value in the positive $\delta^{13}\text{C}$ excursion ACBE at c. 100.406 Ma (100.5 ± 0.1 Ma in GTS 2020). The Natih F and G correlate to Straton 249 (100.406–100.811 Ma) in uppermost Albion.

NAHR UMR FORMATION

The Natih F and G members, and the Nahr Umr Formation in Oman are calibrated by the 32 Stratons 280 to 249 (113.336–100.811 Ma), but these have not been individually identified. The formation is latest Aptian to late Albian (see review and orbital calibration in [Al-Husseini, 2021b](#)). Based on palynology and the identification of four Nahr Umr stratons the Aptian-Albian transition is dated between 112.961 and 112.151 Ma (see review and orbital calibration in [Al-Husseini, 2021c](#)).

SHU'AIBA FORMATION

The Shu'aiba Formation in Oman is calibrated by the 25 stratons 305 to 281 (123.491–113.336 Ma), and assigned to the Aptian Stage (see review and orbital calibration in [Al-Husseini, 2021c](#)). In GTS 2020 the Aptian/Albian Boundary is estimated at 113.2 ± 0.3 Ma compared to the stage transition between 112.961 and 112.151 Ma in the Orbital Scale (see Nahr Umr Formation).

In GTS 2020 the Barremian/Aptian Boundary is estimated at 121.4 ± 0.6 Ma compared to 123.491 Ma for base of the Shu'aiba Formation in the Orbital Scale. The difference of nearly 2.0 Myr for base Aptian and base Shu'aiba might be resolved if the Shu'aiba low stand wedge at Wadi Baraka is late Barremian rather than early Aptian. The wedge consists of Stratons 305 to 302 (123.491–121.871 Ma) and if it is Barremian then the base Aptian would occur at the top of the wedge and would have an age of 121.871 Ma and within the estimate of 121.4 ± 0.6 Ma in GTS 2020.

KHARAIB FORMATION

The Uppermost Lekhwair and Kharaib Formations in Oman represent the Barremian Stage (see review and orbital calibration in [Al-Husseini, 2021c](#)). It is calibrated by the seven Stratons 312 to 306 (126.326–123.491 Ma). The age for base Barremian Stage in GTS 2020 is 126.3 $\pm$ 0.7 Ma, and consistent with the orbital calibration at 126.326 Ma.

The formations below the Kharaib Formation in Oman are diachronous, and consist of numerous clinofolds in the subsurface that are difficult to correlate to stratons.

LATE JURASSIC TO LATE VALANGINIAN FORMATIONS

This very long interval is bounded by the Callovian/Oxfordian (Middle/Late Jurassic) Boundary and Valanginian/Hauterivian Boundary in Early Cretaceous (see review and orbital calibration in [Al-Husseini, 2021d](#)). In GTS 2020 the Callovian/Oxfordian Boundary is estimated at 161.5 ± 1.0 Ma, which correlates closely to the predicted age of SB 11 at 161.966 Ma. The Valanginian/Hauterivian Boundary is estimated at 132.6 ± 0.6 Ma in GTS 2020, which correlates closely to the predicted age of SB 9 at 132.806 Ma. The older boundary correlates to the pre-Hanifa Unconformity, and the younger one to the late Valanginian Unconformity (pre-Biyadh Unconformity in Saudi Arabia), both of which are recognized across most of the Arabian Plate.

The numerical age correlation of two regional unconformities in the Arabian Plate to two orbiton-scale glacio-eustatic unconformities predicted by the Orbital Scale supports the stratigraphic significance of orbitons. This long interval contains Orbitons 11 and 10 consisting of Stratons 400 to 329. Some of the stratons in the Hanifa, Jubaila and Arab Formations have been tentatively correlated to high-frequency sequences at outcrop and to a lesser extent based on ammonites (see review and orbital calibration in [Al-Husseini, 2021d](#)). The sequence stratigraphy of the Hith, Sulaiy, Yamama and Buwaib formations are partially interpreted but without age-indicative biostratigraphy and cannot be correlated to GTS 2020.

DHRUMA FORMATION AND TUWAIQ MOUNTAIN LIEMESTONE

The Dhruma Formation and Tuwaiq Mountain Limestone span the Bajocian, Bathonian and Callovian Stages based on ammonite stratigraphy. In GTS 2020 the Aalenian/Bajocian Boundary is estimated at 170.9 ± 0.8 Ma, which correlates closely to the predicted age of SB 12B at 171.688 Ma. As noted above,

the Callovian/Oxfordian Boundary at 161.5 ± 1.0 Ma correlates closely to SB 11 at 161.966. The two numerical age correlations imply the Dhurma and Tuwaiq Mountain formations consist of Dozons 12B and 12C and the 24 Stratons 404 to 401.

Stratons 442 to 423 are represented by a hiatus that spans the late Toarcian and the Aalenian.

MARRAT FORMATION

The Marrat Formation is dated by ammonites, and consists of the 12 Stratons 454 to 443 in Orbiton 13. The base of the formation is an onlap surface at base Toarcian at 183.836 Ma, also referred to as the pre-Marrat Unconformity. In GTS 2020 the base Toarcian is estimated at 184.2 ± 0.3 Ma.

UPPER MINJUR MEMBER

In Saudi Arabia the Upper Minjur Member spans the latest Rhaetian (latest Triassic) up to the late Pliensbachian pre-Marrat Unconformity (Issautier et al., 2019). The Orbital Scale predicts SB 14B occurs at 200.846 Ma, which is about one straton younger than the estimated age of the Triassic/Jurassic Boundary at 201.4 ± 0.2 Ma in GTS 2020.

Issautier et al. (2019, see their figure 16) depicted a relative sea-level curve with a low stand straddling the Triassic/Jurassic (Rhaetian/Hettangian) Boundary, and the Jurassic transgression starting in early Hettangian. Haq (2018) estimated the Triassic/Jurassic Boundary at 201.3 Ma and interpreted a low stand between Hettangian SB JHe1 (201.3 Ma, base Jurassic), and SB JHe2 (200.8 Ma) in earliest Hettangian. The two SBs bound a c. 0.5 Myr sequence that closely correlates to the boundaries of low stand Straton 496 (14A-12) between 201.251 and 200.846 Ma. This correlation implies the Rhaetian-Hettangian low stand correlates to low stand Straton 14A-12, and SB 14B occurs in earliest Hettangian Straton 495 (14B-1).

The Upper Marrat Member consists of the 41 Stratons 496 to 455, and T-R Sequences 5 to 9 (Issautier et al., 2019) ranging in thickness from c. 25 to 40 m at outcrop. Sequences 5 to 9 are not assigned to specific stages by biostratigraphy (Hettangian, Sinemurian and Pliensbachian) and cannot be correlated to GTS 2020.

REFERENCES

- [Al-Husseini, M.I. \(November 5, 2021a\)](#). Glacio-eustatic signature of the Maastrichtian Stage in Arabia. www.orbitalscale.com
- [Al-Husseini, M.I. \(September 14, 2021b\)](#). Glacio-eustasy in the Cenomanian greenhouse. www.orbitalscale.com
- [Al-Husseini, M.I. \(July 5, 2021c\)](#). Orbital calibration of the Aptian Shu'aiba Formation in Arabia. www.orbitalscale.com
- [Al-Husseini, M.I. \(June 24, 2021d\)](#). Orbital calibration of the Late Jurassic Hanifa, Jubaila and Arab Formations, Saudi Arabia. www.orbitalscale.com
- Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G.M. (Eds). Chapter 1, Introduction. The Geologic Time Scale 2020, v. 1, p. 3–20, Elsevier.
- Haq, B.U., 2018. Jurassic sea level variations: a reappraisal. GSA Today (Geol. Soc.) 28, p. 4–10.
- Issautier, B., Le Nindre, Y.M., Hooker, N., Reid, C., Memesh, A., Dini, S., 2019. Depositional environments, age, and sequence stratigraphy of the Minjur Formation in outcrop and near subsurface – Central Saudi Arabia. In Al-Anzi, H.R., Rahmani, R.A., Steel, R.J., Soliman, O.M. (Eds.), Siliciclastic reservoirs of the Arabian plate: AAPG Memoir 116, p. 181–184.
- [Matthews, R.K., Al-Husseini, M.I., 2010](#). Orbital-forcing glacio-eustasy: A sequence-stratigraphic time scale. GeoArabia, v. 15, no. 3, p. 155–167.

Geologic Time Scale GTS 2020			Orbital Scale				
			Age	Unit	Straton	Dozon/Orbiton	
PALEOCENE				Lina	?		
LATE CRETACEOUS	*	66.04 ± 0.05	65.981				
	Maastrichtian		6.48 Myr	Hajajah	179–164	16	Orbiton 5
		72.2 ± 0.2	72.461	?			
	Campanian			Khanasir			SB5 — 74.486
		83.7 ± 0.5		?			
	Santonian						Orbiton 6
	Coniacian		21.465 Myr	Hiatus	230–180	53	
EARLY CRETACEOUS		85.7 ± 0.2					
	Turonian						SB6 — 89.066
		89.4 ± 0.2					
	δC	93.9 ± 0.2	93.926				
	Cenomanian		6.48 Myr	Natih A–E	248–230	19	Orbiton 7
		100.5 ± 0.1	100.406				
	Albian		13.77 Myr	G/F	280–249	34	SB7 — 103.646
		113.2 ± 0.3	113.336	Nahr Umr			Orbiton 8
	Aptian		10.125 Myr	Shu'aiba	305–281	25	SB8 — 118.226
	?	121.4 ± 0.6	123.491				
LATE JURASSIC	Barremian		2.835 Myr	Kharaib	312–306	7	Orbiton 9
	*	126.3 ± 0.7	126.326	U. Lekhwair			
	Hauterivian		7.29 Myr	Clinofoms	328–313	18	
		132.6 ± 0.6	132.806				SB9 ~ 132.806
	Vanlanginian			Buwaib			
		137.7 ± 0.5		Yamama			Orbiton 10
	Berriasian			Sulaiy			
MIDDLE JURASSIC		143.1 ± 0.6	29.6 Myr	Hith	400–329	72	SB10 — 147.386
	Tithonian			Arab			
		149.2 ± 0.7		Jubaila			Orbiton 11
	Kimmeridgian			Hanifa			
	Oxfordian						
EARLY JURASSIC	*	161.5 ± 1.0	161.966				SB11 ~ 161.966
	Callovian						
	*	165.3 ± 1.1	9.72 Myr	Tuwaiq Mountain			
	Bathonian				424–401	24	Dozon 12C and 12B
	*	168.2 ± 1.2		Dhurma			
	Bajocian		171.686				SB12B ~ 171.686
EARLY JURASSIC	*	170.9 ± 0.8					
	Aalenian		8.10 Myr	Hiatus	442–423	20	Dozon 12A
		174.7 ± 0.8	178.900				SB12 — 176.546
	Toarcian		4.86 Myr	Marrat	454–443	12	Orbiton 13
	*	184.2 ± 0.3	183.386				
	Pliensbachian						SB13 — 186.266
EARLY JURASSIC		192.9 ± 0.3					
	Sinemurian		16.605 Myr	Upper Minjur	496–455	41	Dozon 14C and 14B
	Hettangian		199.5 ± 0.3				
			201.4 ± 0.2				SB14B — 200.846

Figure 1: Orbital calibration of Jurassic and Cretaceous with 0.405 Myr stratons. Asterix (*) indicates biostratigraphic constraint, δC carbon-isotope correlation, and question mark major difference.