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STRATIGRAPHIC NOTE

Jurassic-Cretaceous Arabian orbital stratigraphy: The AROS-JK Chart

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An orbital-forcing, glacio-eustatic model predicts that the depositional durations of transgressive-regressive sequences manifest a periodic hierarchy. Model fourth-, third- and second-order sequences have discrete depositional periods that range from 405 thousand years (Ky) to 14.58 million years (My) (Figure 1; Matthews and Frohlich, 1998, 2002; Immenhauser and Matthews, 2004; Al-Husseini and Matthews, 2005a). This note is part of the ongoing Arabian Orbital Stratigraphy (AROS) program aimed at correlating the model to the sequence stratigraphy of the Arabian Plate.

This note accompanies the enclosed Jurassic-Cretaceous Chart (AROS-JK Chart) and focuses on recently documented and dated Jurassic and Cretaceous Arabian sequences. The framework is based on tuning the LA04 orbital-forcing computation of Laskar et al. (2004) and glacio-eustatic parametric forward modeling (Matthews and Frohlich, 2002, p. 515) by R.K. Matthews. Second-order sequence boundaries are here predicted to have occurred every 14.58 My, starting at either 11.3 ± 0.3 or 16.1 ± 0.3 Ma, depending on the choice among geologically reasonable model parameters. The correlation to Jurassic and Cretaceous regional unconformities-hiatuses, with ages estimated from GTS 2004 (Gradstein et al., 2004), supported a correlation to the 16.1 Ma second-order model (Figure 2).

In this note we position representative second-, third- and possible fourth-order Arabian depositional sequences, maximum flooding surfaces and time-marker units in the model framework (AROS JK-Chart). With the exception of the Arabian Plate maximum flooding surfaces (Sharland et al., 2001) most of these sequences, surfaces and time-marker units are only defined locally to semi-regionally (e.g. outcrop, concession, petroleum field, etc.); their extent (or lack of) across Arabia remains to be evaluated. The bibliographic references used to date and correlate the sequences and time-rock units are listed in descending stratigraphic age below.

RECENT STRATIGRAPHIC SOURCES

Geological Time Scale GTS 2004 (Gradstein et al., 2004).
Arabian Plate Maximum Flooding Surface, MFS (Sharland et al., 2001; Davies et al., 2003; Simmons et al., 2007).

Aruma Group (Turonian-Paleogene)

Saudi Arabia, Aruma Formation (Vaslet et al., 1983, 1991; Le Nindre et al., 1990; Philip et al., 2002; Al-Husseini and Matthews 2005b; Y.-M. Le Nindre et al., *in* preparation): Paleogene Lina Member; Late Maastrichtian Hajajah Member, *Aruma Sequence 3* (sub-sequences Ar 3a to 3f) and *Aruma Sequence 2* (sub-sequences Ar2a to 2d); and Late Campanian-Maastrictian Khanasir Member, *Aruma Sequence 1* (sub-sequences Ar1a to Ar1c).

Iraq, Aruma Group (van Bellen et al., 1959; Jassim and Goff, 2006; Haddad and Ameen, 2007): Campanian-Maastrichtian Shiranish Formation; Campanian Lower Hartha Formation, *Sequence C3*; Santonian?-Campanian Sa'adi Formation, *Sequences C1 and C2*; Santonian-Campanian? Tanuma Formation, *Sequences B2 and B3*; and Turonian?-Coniacian Khasib Formation, *Sequence B1*.

Turonian Unconformity-Hiatus (Searle, 2007)

Wasia Group (Late Aptian-Turonian)

Kuwait, Wasia Group (Al-Fares et al., 1998): Cenomanian Mishrif Formation, Cenomanian Rumaila Formation, Cenomanian-Albian Ahmadi Formation, Albian Wara Formation, Albian Mauddud Formation, Albian Burgan Formation and Late Aptian "Unnamed Clastics Formation".

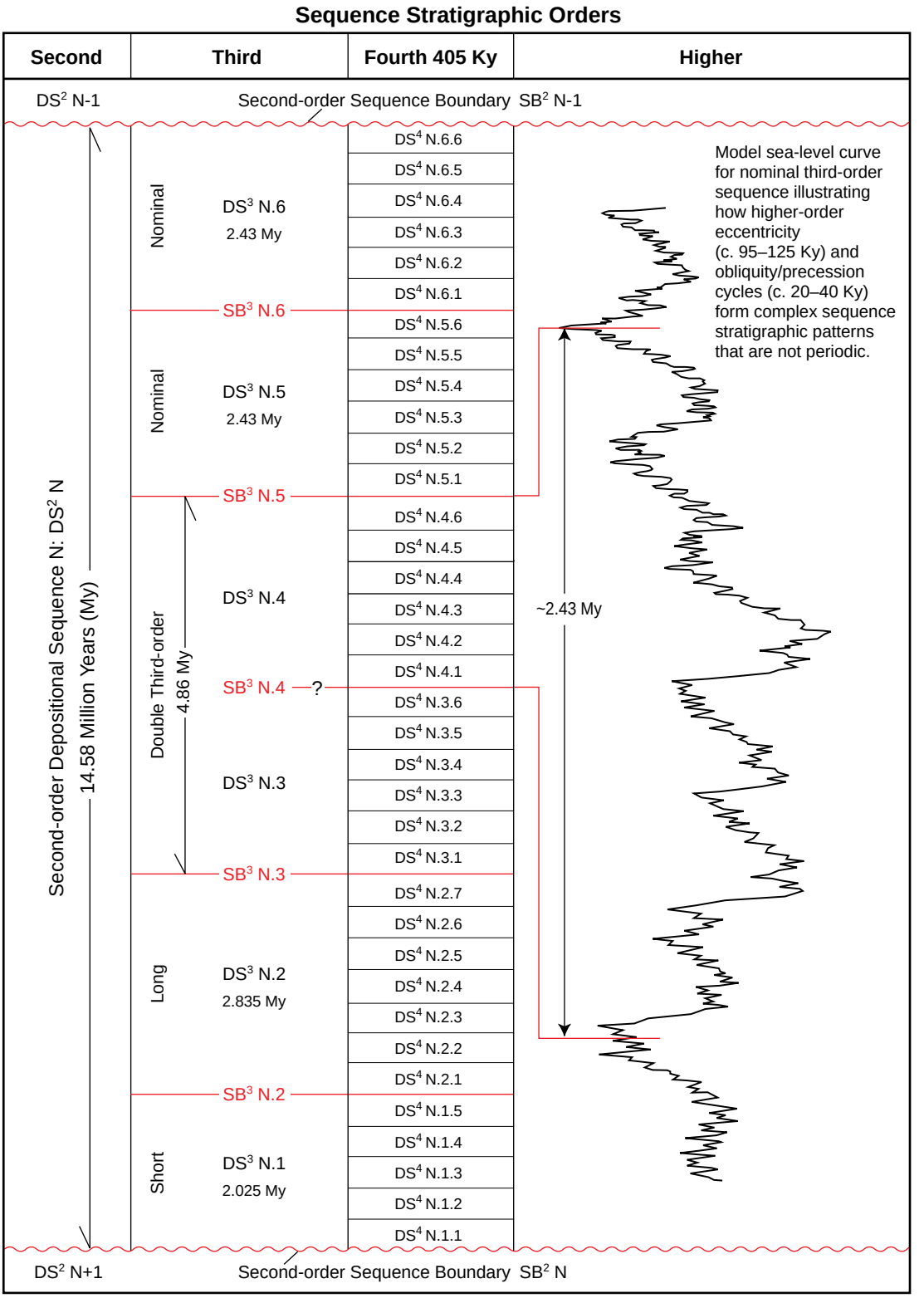

Figure 1: The order of transgressive-regressive depositional sequences (DS) and sequence boundaries (SB) is indicated by superscripts 2 to 4. A model second-order sequence (DS² N) has a depositional period of 14.58 million years (My) and is bounded by regional second-order sequence boundaries (SB² N and SB² N-1, unconformities in proximal settings). A complete DS² consists of six third-order sequences (DS³ N.1 to DS³ N.6) with depositional periods of 2.025 My (short), 2.43 My (nominal), 2.835 My (long) that are bounded by third-order sequence boundaries (SB³). Even-odd DS³ pairs (e.g. DS³ N.3 + N.4) always form double-third-order sequences with a period of 4.86 My, but may not always clearly separate as two DS³s. The sequential arrangement of DS³s (e.g. short-long or nominal-nominal, etc.) is shown schematically. Fourth-order sequences have a period of 405,000 years (405 Ky) and are uniquely identified as DS⁴ N.M.1 to N.M.5, or to N.M.6 or to N.M.7.

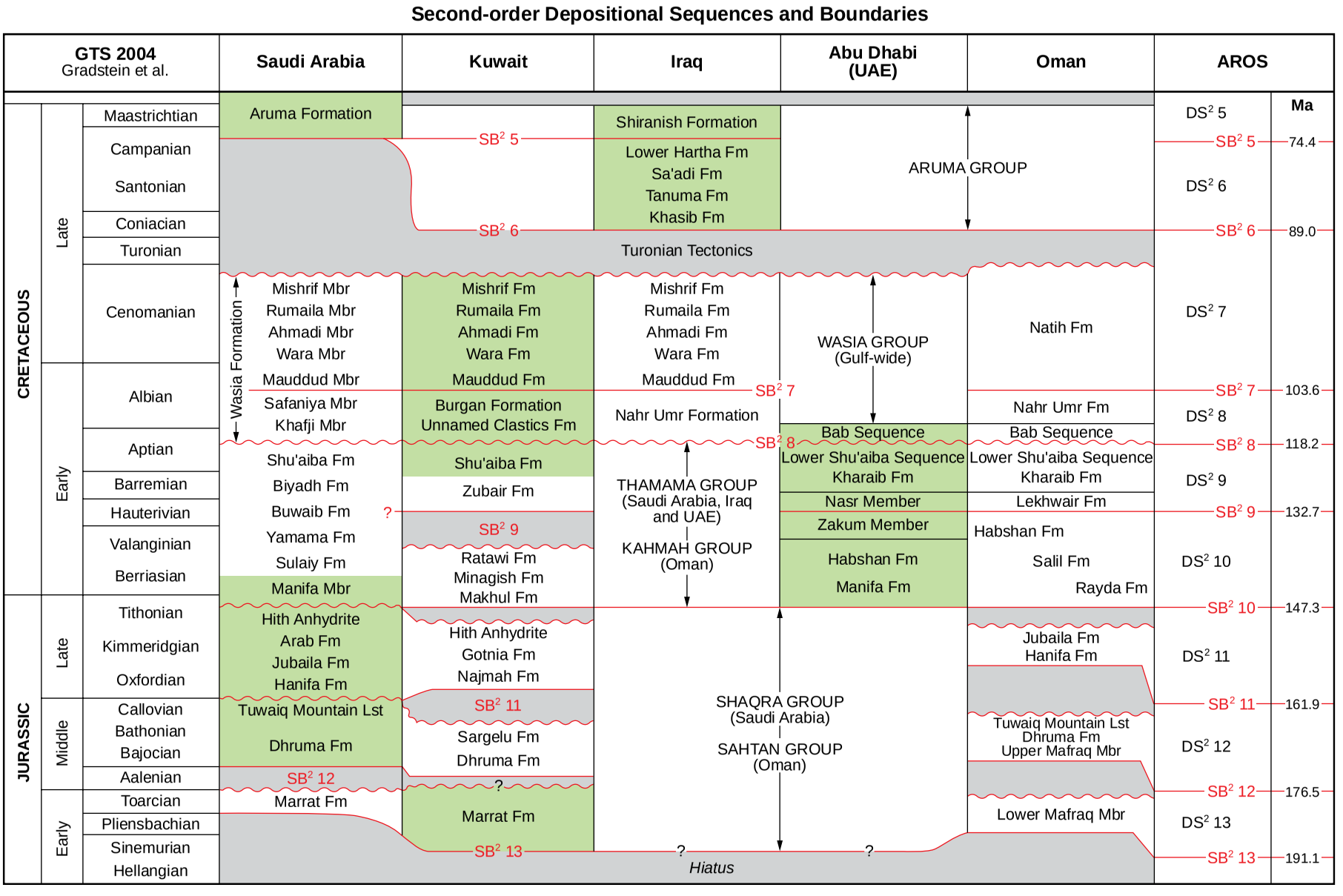

Figure 2: Cretaceous and Jurassic rock units (groups, formations and key members) are shown in terms of the second-order AROS framework. Hiatuses are indicated in grey between unconformity below, and transgressive surface above. Detailed representative successions in the AROS-JK Chart are highlighted in green.

Kuwait, Burgan Formation (Kirby and Al-Humoudi, 1996; Kirby et al., 1998): Albian Upper Third Sand (Mauddud Formation and mfs 3.U.D to 3.U.A); Albian Middle Third Sand (mfs 3.M.F to 3.M.A); Albian Lower Third Sand (mfs 3.L.E to 3.L.A); Albian Dair Limestone; Albian Upper Fourth Sand (mfs 4.U.D to 4.U.A); Late Aptian?-Albian Middle Fourth Sand (Main Sand); and Late Aptian Lower Fourth Sand ("Unnamed Clastics Formation").

Thamama Group (Late Tithonian-Aptian)

Oman and UAE, Kharaib and Shu'aiba Formations (Boichard et al., 1995; Taher, 1997; van Buchem et al., 2002; Boote and Mou, 2003; Immenhauser et al., 2004; van Buchem, *in* preparation): Late Aptian *Bab Sequence*; Early Aptian *Lower Shu'aiba Sequence* (including Hawar sub-sequence); Late Barremian *Upper Kharaib Sequence* (Thamama Zone B and Dense B); and Early Barremian *Lower Kharaib Sequence* (Thamama Zone C and Dense C).

UAE, Abu Dhabi, Lekhwair Formation, Nasr Member (Taher, 1997): Hauterivian-?Barremian Thamama Zone D to Dense E.

UAE, Abu Dhabi (Aziz and El Sattar, 1997): Early Hauterivian *Zakum Sequence IV* (Thamama Zone F to Dense H); Late Valanginian *Habshan Sequence III*; Early Valanginian *Habshan Sequence II*; and Berriasian *Habshan Sequence I*.

UAE, Abu Dhabi, Tithonian Manifa Formation (Grotsch et al., 2003).

Shaqra Group (Jurassic)

Saudi Arabia, Shaqra Group (Powers, 1968; Wilson, 1985; Manivit et al., 1985a, b, 1986, 1990; Enay, 1987; Vaslet et al., 1983, 1991; Le Nindre et al., 1990; Meyer et al., 1996; Hughes, 1996, 2004, 2006; Fischer et al., 2001; Haq and Al-Qahtani, 2005; G. Grabowski, written communication, 2006; Al-Husseini et al., 2006; Hughes et al., 2006; Enay et al., *in* preparation): Tithonian Hith Anhydrite: Manifa Member, Transition Member and Main Hith Anhydrite; Tithonian?-Kimmeridgian Arab A, B and C members; Kimmeridgian Arab-D Member, Arab-D Anhydrite, Arab-D Reservoir, Arab-D Reservoir Zones 1 to 4, Arab-D Layers 1 to 18, Biozones D1 to D3; Kimmeridgian Jubaila Formation, units J1 and J2; Oxfordian Hanifa Formation, *Ulayyah and Hawtah Sequences*; Callovian Tuwaiq Mountain Limestone, units T3 to T1, Daddiya, Maysiyah and Bladiyah members; Dhruma Formation, Lower Member (Dhibi Limestone and Dhruma Shale), Middle Member, and Upper Member (Hisyan and Atash); Dhruma Formation: Bajocian units D1 to D3, Bathonian units D4 to D6 and Callovian unit D7.

Kuwait, Late Sinemurian? to Early Aalenian? Marrat Formation (Yousif and Nauman, 1997; Al-Sahlan, 2005; G. Grabowski, written communication, 2006).

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The authors welcome comments on the application of the orbital-forcing glacio-eustatic model. For further information about modeling concepts, write to Dr. Robley K. Matthews (RKM@brown.edu). To comment on the regional geology depicted in Figure 2 and the AROS-JK Chart, write to Dr. Moujahed Al-Husseini (geoarabi@batelco.com.bh). For further information about participating in the Arabian Orbital Stratigraphy (AROS) Consortium write to both authors. AROS proposal available upon request. The design and drafting by Heather Paul is appreciated.