The mid-Cretaceous Natih Formation in northern Oman: a model for platform-intrashelf basin depositional systems and associated petroleum habitat.

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Appendices captions

Appendix 1. Lithostratigraphic members and sequence definition in the Natih Formation (modified after Grélaud *et al.*, 2006). Lithostratigraphic members (Natih G to A) are based on wireline log signature. They are correlated to the four third-order stratigraphic sequences (I to IV) which were determined by van Buchem *et al.* (2002a). In this field guide, the authors propose an updated sequence stratigraphic scheme (yellow column).

Appendix 2. Stop 1, point 1a overview. (a) Bedding pattern of the Natih Sequence I (Natih G, F and E members) in Wadi Mu'aidin; (b) The exposure surface at the top of Sequence I corresponds to IS2 incision surface in other sections (J. Madar, J. Madmar, J. Shams, etc.).

Appendix 3. Stop 1. Natih sequences II and III (Natih D, C, B and A members) in Wadi Mu'aidin. The carbonate depositional systems M-IP, C-IP, R-IB and P-IB refer to Fig. 6.

Appendix 4. Stop 1, point 1e. Top Natih unconformity in Wadi Mu'aidin and on seismic data. (a) The top of Sequence IV is marked by an iron-rich surface recording a subaerial exposure and incision; (b) The incision is filled with green marls overlain by a bioclastic channel capped by iron oolites (Sequence V). The top Natih unconformity corresponds to the top of this iron oolites bed. It is overlain by hemipelagic marls of the Muti Formation; (c) Seismic amplitude map along Top Natih horizon (44 ms below) showing a complex of narrow and wider incisions in north Oman (modified after Droste & Van Steenwinkel, 2004).

Appendix 5. Stop 2. The Natih Formation in Jabal Madar (outcrop and well data): facies succession and sequence stratigraphy (modified after van Buchem *et al.*, 2002a).

Appendix 6. Stop 2. Incisions at the top of Sequence I (Natih E member) in Jabal Madar. (a) Eastern outcrop transect (see (c) for location) showing geometries and facies evolution from the first incision surface (IS1) to the top of the second incision fill (modified after Grélaud *et al.*, 2006). The first bed of Sequence II is also represented at the top of the transect. The correlation of two marker beds in the strata below IS1 reveals the presence of faults that are sealed by the first incision surface; (b) Outcrop view of the F section in the Eastern outcrop transect (see (c) for location). IS2 incision surface is indicated with a red arrow; (c) Satellite image of Jabal Madar outcrop, overlain by a map of IS2 incision (shaded in green) (modified after Grélaud *et al.*, 2006). The locations of measured sections are indicated. This map was made by analysing the facies and geometries in the incision fill on the transects and by assuming that only one incision is present, that it has a constant incision width across the Jabal and that the width of the incision on the eastern transect is its true width; (d) Schematic drawings showing the successive phases of erosion and fill of IS1 and IS2 incisions in Jabal Madar. 1) High-energy lag deposit above the first incision surface

(IS1); 2) Low-energy fill; 3) High-energy final fill of IS1 (development of tidal channels); 4) Erosion of previous IS1 fill by the second incision surface (IS2); 5) High-energy lag overlain by low-energy clayey fill of IS2; and (e) Seismic-amplitude map of the IS2 reflection in north Oman, showing evidence of incision (modified after Grélaud *et al.*, 2006). See Appendix 12 for more details;

Appendix 7. Stop 2, point 2d. Dissolution breccia associated with the exposure of the carbonate platform at the top of Sequence I in Jabal Madar.

Appendix 8. Stop 2, point 2c. Outcrop view of Natih Sequence II in Jabal Madar.

Appendix 9. Stop 2, point 2d. Rudist / Stromatoporoïd floatstone within the Natih D member, Sequence II.2 in Jabal Madar: a very occasional inner-platform « biostrome ».

Appendix 10. Stop 4, point 4a. (a) Facies and bedding pattern of the intrashelf-basin organic-rich facies in the lower part of Sequence I (Natih E member) in Jabal Madmar. (b) View of the cliff-forming GST/PST interval below the first incision surface (IS1). The brown bed visible at the top of the cliff corresponds to the lag deposit at the base of the incision fill. (c) Natih Sequence I measured section showing the stratigraphic location of A and B outcrop photos (yellow arrows).

Appendix 11. Seismic map of the migrating clinoform belts in Sequence I (modified after Grélaud *et al.*, 2006). (a) Seismic amplitude map on a horizon slice (copy of top Sequence I horizon minus 25 ms). The intersection between the horizon and clinoforms is highlighted by seismic amplitude variations, allowing to map out clinoform belts; (b) Interpretation: 3D mapping of clinoforms. Solid hatched black lines (r4, r5) correspond to the maximum extent of the successive platform margins which developed with « low-angle » clinoforms (L). Hatch indicates direction of progradation. Dotted black lines correspond to the maximum extent of the successive platform margins that developed with « high-angle » clinoforms (forced-regressive wedges, H). The position of the seismic line shown on Fig. 25 is marked with a red line.

Appendix 12. IS2 incisions on seismic data (modified after Grélaud *et al.*, 2006). (a) Seismic amplitude map of the IS2 reflection and its interpretation, showing three incision geometries; (b) Seismic line crossing one of IS2 incisions. IS2 incisions are better imaged than the IS1 incisions due either to a greater thickness or to a slower velocity of the incision fill (or both). The significant velocity « push down » of six reflections below the incision and the presence of shadow bands below its edges suggest a slow velocity fill (i.e. clays) in this incision.

Appendix 13. (a) Schematic map of Natih Sequence I clinoforms (represented by the location of their offlap-break) interpreted on seismic data; (b) Schematic regional sequence-stratigraphic outcrop-surface correlation of Natih sequence I over the northern part of Oman. (Modified after Grélaud, 2005).

Appendix 14. Interpretation of top Natih Sequence I incisions and related heterogeneities (modified after Grélaud *et al.*, 2006). (a) Schematic correlation of the stratigraphic unit between the two incision surfaces in the upper part of Sequence I (Sequence I.7) between Jabal Madar and Jabal Madmar. This diagram illustrates the fill of IS1 incisions on a proximal-distal transect. The incisions are filled by three successive facies units: 1) a high energy lag deposit at the base, followed by 2) a low-energy muddy facies above and topped by 3) a higher-energy facies unit corresponding to tidal channel deposits; (b) Schematic interpretation of the Natih incision fill succession. The lag was probably deposited during a phase of tidal erosion at the first flooding of the platform after exposure; the muddy unit may correspond to a phase of development and migration of bioclastic shoals on the platform margin which would protect the incisions from high-energy conditions; the development of tidal channels re-occupying the incisions in the upper part of the fill probably corresponds to the phase of flooding of the platform, during which a larger volume of water was available to amplify or renew tidal processes on the platform. The tidal channel deposits in the upper part of the incision fill are characterised, in the distal position (Jabal Madmar), by lateral accretion geometries, interpreted as the result of low-energy 'point bar' migration.

Appendix 15. Jabal Madmar outcrop correlation transect showing facies evolution and geometries between incision surfaces IS1 and IS2 (modified after Grélaud *et al.*, 2006). In Jabal Madmar, the IS1 surface is highlighted by intense silicification and chert nodules. IS1 fill consists of a coarse lag interval of variable thickness at the base, overlain by entirely to partially dolomitised mudstone with orbitolinids. Above, laterally stacked bedsets, interpreted as lateral accretion within a migrating tidal point bar, form the top of IS1 incision fill. Unit 1 (early TST), is much thicker in Jabal Madmar than in Jabal Madar. IS2 incision erodes down to the lower part of Unit 1 deposits. IS2 incision is filled with a coarse lag interval overlain by 13 m-thick marls and green clays. The last carbonate bed at the top of the IS2 fill is capped by a hardground.

Appendix 16. Stop 4, point 4d. Overview of the upper part of the Natih Formation in Jabal Madmar NE section. Note the very similar stacking pattern of the three 3rd-order sequences, starting with a clay-carbonate interval (ETST) and overlain by a carbonate unit, well-stratified at the base and more massive above (LTST / HST).

Appendix 17. Stop 5, points 5b, c and d. Overview of Natih Sequences II and III in Jabal Madmar NW. The stacking pattern of these sequences is very similar to the one observed in Jabal Madmar NE (Ap. 16) and in Jabal Salakh SE (Ap. 22), starting with a clay-carbonate interval (ETST) and overlain by a carbonate unit, well-stratified at the base and more massive above (LTST / HST). Note the thickening-up pattern of the high-frequency sequences (II.1, II.2…) building the third-order Sequences II and III. The location of the visited outcrops 5b, 5c and 5e is marked with a yellow star.

Appendix 18. Stops 5 and 8 compared. Lateral facies variation within the transgressive systems tract of Natih Sequence III, from (a) outer-ramp bioclastic wackestone (Jabal Madmar) to (b) organic-rich mudstone accumulated in the Natih B intrashelf basin (Jabal Qusaibah).

Appendix 19. Regional transect of the Natih B member along the Adam Foothills and to the Natih Field (modified after van Buchem *et al.*, 2005). Organic matter in the outcrop sections is overmature, but in the Natih-68 well it is immature. Carbonate marker beds are indicated, as well as high-gamma-ray intervals. U content is interpreted as a proxy for organic-matter content. Note lateral facies and thickness change from thinner organic-rich intrashelf carbonates in the west, to thicker organic-lean shallow water carbonates in the east.

Appendix 20. Stop 6, point 6a. (a) Overview of Natih Sequence I in Jabal Salakh SE, above the clayey Nahr Umr Formation. In the organic-rich interval, the stacking pattern allows to define several units (U3 to U6); (b) Presence of time-equivalent units (V to Z) in Jabal Madmar with two thin (1 m) organic-rich intervals (black arrows); (c) In the more distal Jabal Salakh area, one thick (30 m) organic-rich interval is observed (black arrow) in the intrashelf basinal facies succession.

Appendix 21. Stop 7. Outcrop locations in Jabal Salakh SW area.

Appendix 22. Stop 7. Overview of Natih sequences II and III on the southern flank of Jabal Salakh (Salakh SW). Note the thick development of intrashelf basin deposits in the Natih B member (Seq. III).

Appendix 23. Stop 8, point 8c. Outcrop views of the sandwave complex located in the upper part of Sequence II on the northern flank of Jabal Qusaibah (see Fig. 29) (modified after Grélaud *et al.*, 2010). (a) Overview of the stratigraphy of the Jabal Qusaibah outcrop; (b) Photograph showing the sandwave complex and its north-eastern termination. (1) lower unit, (2) middle unit, (3) upper unit; (c) This complex of coarse-grained bioclastic sandwaves is up to five metres high and presents steep foresets migrating in various directions (overall towards the NE).

Appendix 24. Stop 8, point 8f. Detailed view of the intrashelf basin facies of the Natih B member in Jabal Salakh. The laminated intervals are characterised by a higher organic matter content. *Exogyra* oyster-rich levels occur frequently in the intrashelf basin deposits.

Appendix 25. The Natih petroleum system: reservoir layering in Natih 68 well and correlations with the Adam Foothills outcrop analogue (modified after van Buchem *et al.*, 2002a and 2005). Source rocks in the well are immature (HI between 450 and 700), while they are overmature in the outcrops.

Appendix 26. Stop 8, point 8i. Top Natih unconformity in Jabal Qusaibah.

Appendix 27. Stop 11a - The Cretaceous carbonate platform in Wadi Nakhr canyon (view from Jabal Shams). (a) overview of the complete Cretaceous succession above the top Jurassic unconformity (blue dashed line); (b) more detailed view of the Kahmah and Wasia Groups.

Appendix 28. Stop 11, point 11c. (a) Jabal Shams correlation transect showing the evolution of geometries and facies in the fill of the IS2 incision in Jabal Shams, which was located closer to the ocean-facing platform margin during Natih times (modified after Grélaud *et al.*, 2006). The irregular surface at the base of the incision (IS2) is a result of the non-aligned position of the sections along the transect. Note also the large vertical exaggeration (x 15). The incision fill can be divided into three sub-units. Where the incision is the deepest, a first phase of fill is characterised by several channel-shaped beds made of Gst and passing laterally towards the north and south (where the incision was shallower) to Wst/Pst with palaeosoil features. Above this first fill, the second sub-unit is a marly Mst unit, up to 10 m-thick. The last sub-unit is a Pst/Gst bed of irregular thickness showing internal lateral accretion features. It is capped by a hardground; (b) close-up view of the deepest part of the incision. IS2 is marked with a red line; (c) close-up view of the eastern edge of the incision.

Appendix 29. Stop 11, point 11d. Natih Sequence II (Natih D and C members) in Jabal Shams (Robinet *et al.*, 2015).

Appendix 30. Stop 11, point 11c. Extensive tabular homogeneous GST units at the top of transgressive HF cycles (Robinet *et al.*, 2015).

Appendix 31. Stop 11. Detailed architecture of Natih Sequence II.6 on the Jabal Shams plateau. Note the complex evolution of the clinoform geometries related to the progradational / aggradational pattern. This transect based on physical correlations shows for the HF Sequence II.6.16 the clear partitioning between the transgressive muddy deposits preserved by aggradation in the proximal area (west) and the regressive grainy deposits prograding towards the slightly deeper part of the platform (East).