Early Cretaceous Stratigraphy & Reservoirs Architecture

Theme: Regional stratigraphy & reservoir architecture of the Late Jurassic/Early Cretaceous carbonates of the UAE & Oman, depositional environments, facies, static model building, flow unit continuity

Target Reservoirs: all Thamama & Habshan reservoirs, Asab Oolites, Arabs (Shaybah (KSA), Lekhwair, Al Huwaisah, (Oman), Shah, Bab, Bu Hasa, Asab, NEB, Qusawirah, Mender (UAE)

Target Audience: Students and experienced oil company staff (geologists & seismic interpretors, explorationists and reservoir modelers

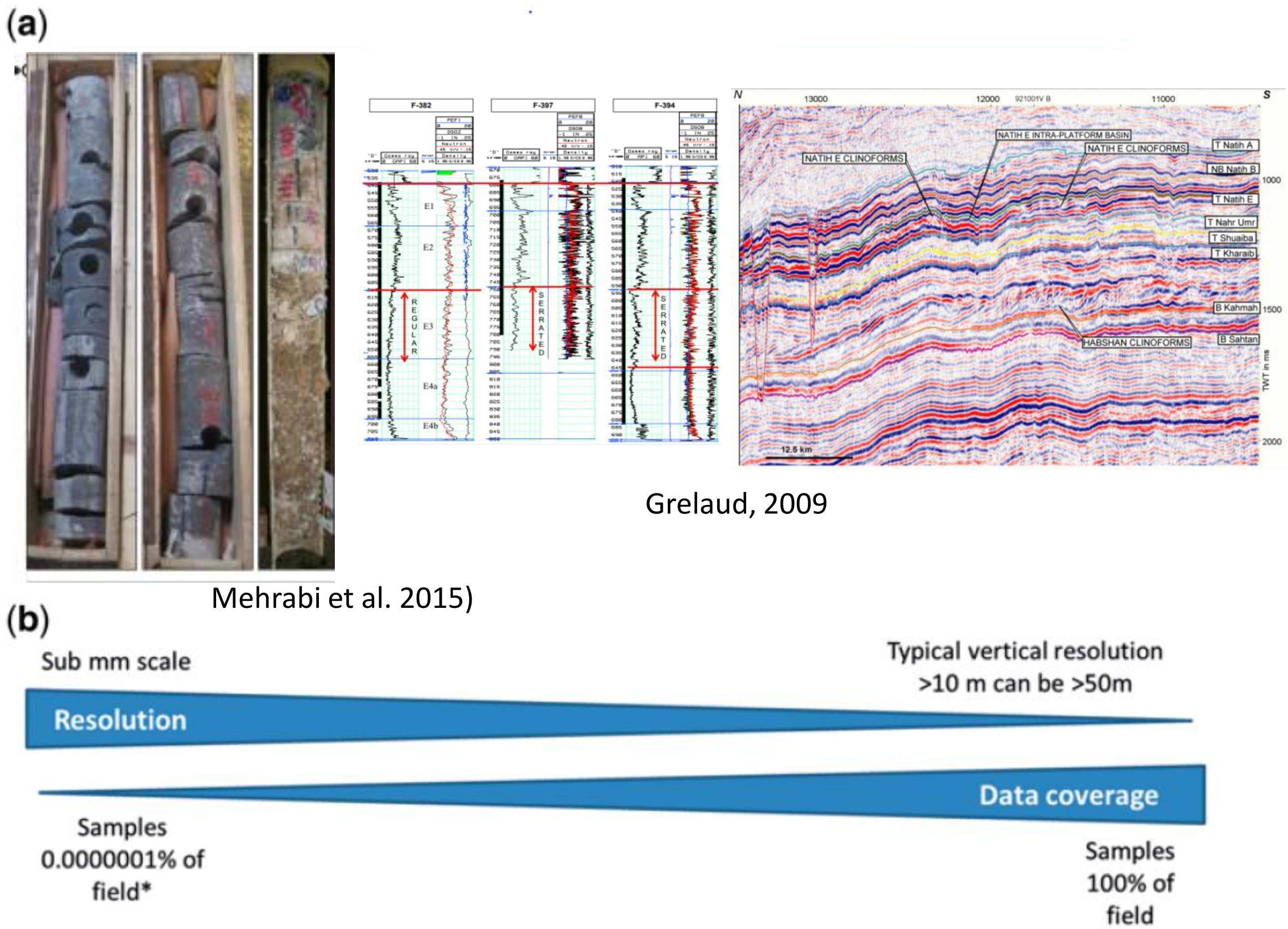


Figure. A. Shu'aiba core (Mehrabi et. al, 2015), log-data, Seismic data (Grelaud, 2009)

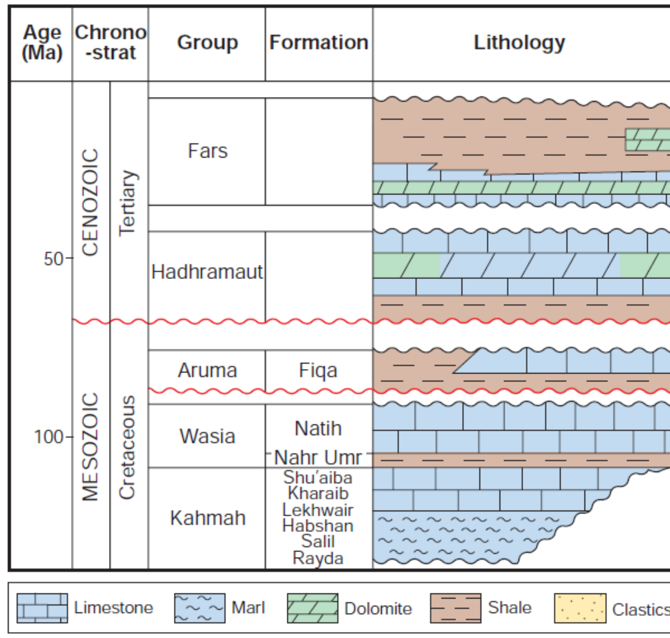
B. Relative proportion of data resolution and coverage between core, well-logs, and seismic (Howell et. al, 2014).

Outcrops are crucial in developing well-informed understanding of any hydrocarbon reservoir, and is illustrated by figure A and B. As observed in figure A and B, the resolution of data reduces as we jump from cores to well-logs to seismic, and similarly the cores and well-logs only provide area specific information while seismic covers the complete field. There are several missing links from cores to well-logs to seismic, which can only be understood utilizing outcrop analogs. The missing links include 3D depositional architecture, facies variations laterally and vertically, and fracture patterns.

Reservoir modeling requires scaling up of data (geological and petrophysical) from cores and well logs. However, in doing so, crucial information about the connectivity of geobodies, their size, and shape could be mis-interpreted. Therefore, there is a need to utilize outcrops to train geologists, seismic interpretors, explorationists, and reservoir modelers with the heterogeneity and architecture of a depositional system, to support them develop more informed reservoir models.

Cretaceous Arabian carbonates are home to some of the biggest hydrocarbon reservoirs in the Arabian peninsula. Due to the interplay of eustacy, climate, paleogeography, and tectonics the emplacement of source, reservoir, and seal took place on the Arabian platform, depositing a thick succession, as much as 1 Km of strata (mostly carbonates). These rocks are producing in the subsurface and are also outcropping in few parts of Arabian peninsula. The outcrops are the windows of opportunity to learn more about the structure, size, and heterogeneity of the subsurface reservoirs. **Oman** is the best location to study in details the Cretaceous Arabian Carbonates, as the outcrops are seismic scale and exposed in 3D.

In general the Cretaceous Arabian rocks in Oman are divided into two groups of rocks – Kamah Grup and Wasia Group separated by an unconformity. The Kamah group lies unconformably over mid-Jurassic rocks and the Wasia Group is overlain by Aruma Group. Each group consists of several formations.



Stratigraphic Column - Cretaceous – Tertiary rocks (Huges Clarke, 1988; Vahrenkamp, 2013).

Jabal Shams

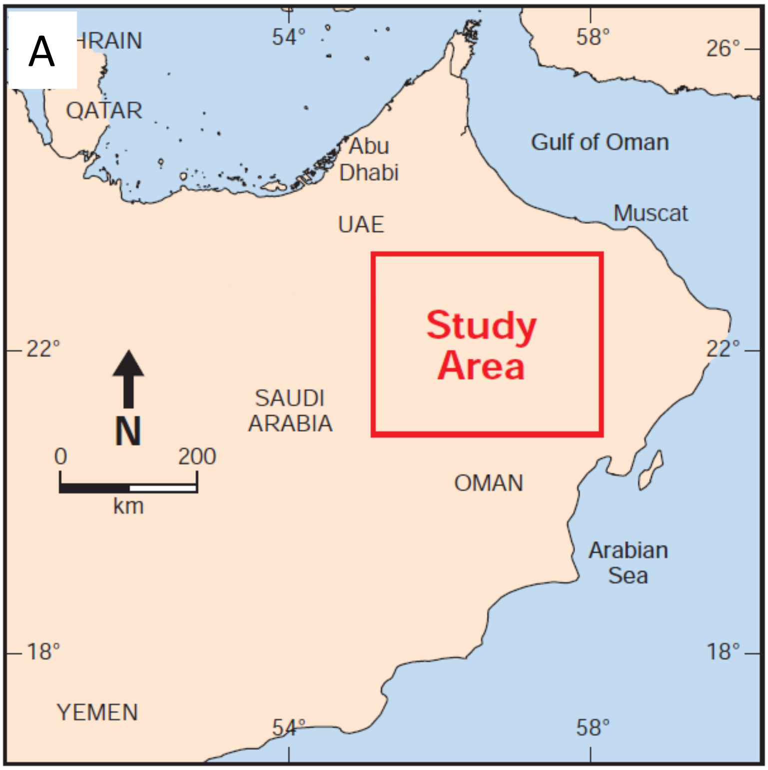


Figure A: Eastern Arabian Peninsula – red rectangle represents the study area where the early Cretaceous rocks are exposed along Wadi's and Jabal's (Vahrenkamp, 2013).

Figure B: Displays the google earth image of the area represented in red rectangle in figure A. Red stars represent the location of field stops.

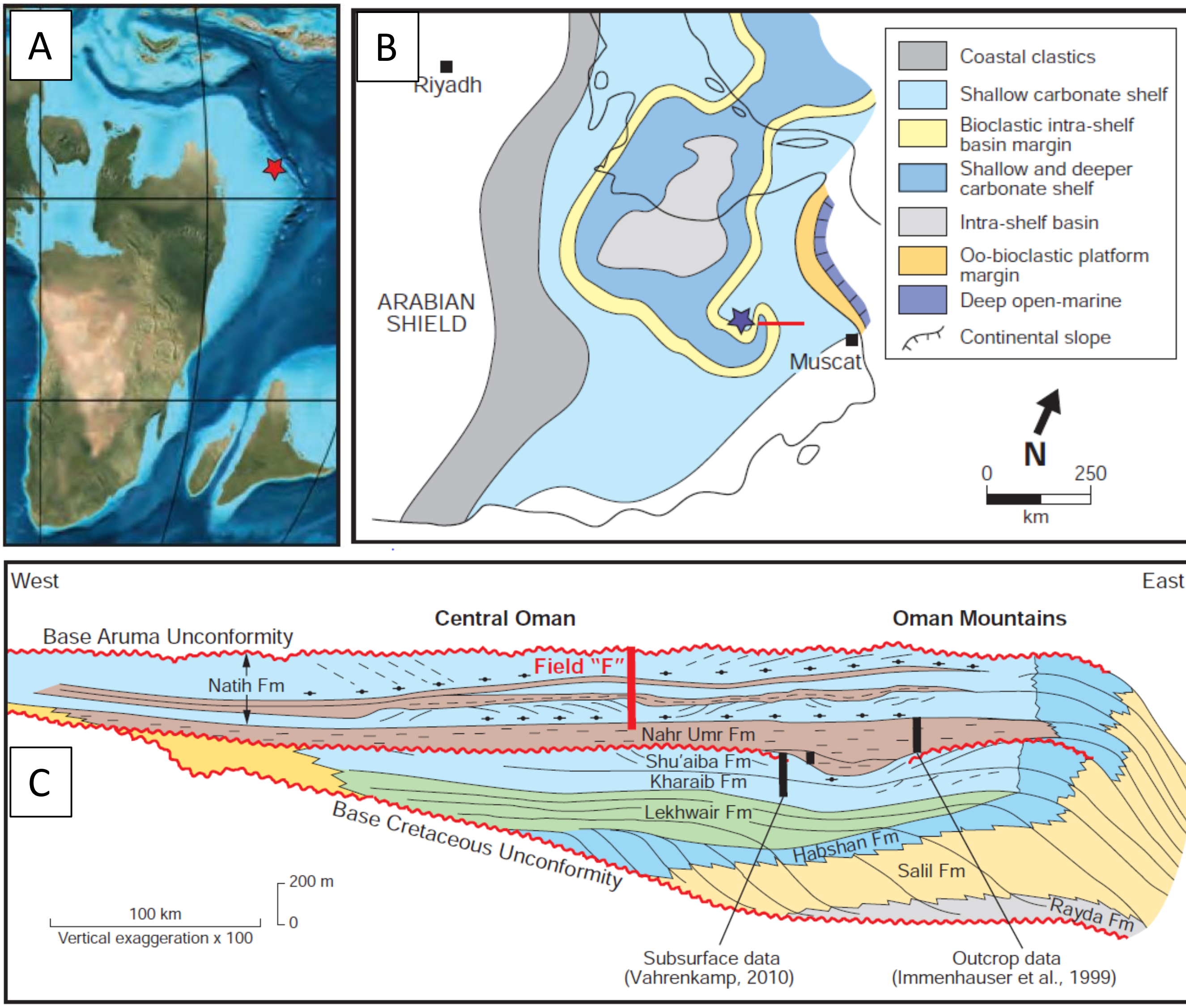


Figure A –Paleogeographic map during Cretaceous where red star represents the study area. Early Cretaceous was a time period of an extensive shallow-water carbonates at the passive northeastern margin of the Africa- Arabia Plate (http:// jan.ucc.nau.edu/~rcb7/mollglobe.html; Vahrenkamp, 2013).

B – Represents the bird's eye view of the Cretaceous platform depositional units (Vahrenkamp, 2013).

C- Depositional setting for the eastern margin of the Arabian Platform bounded by major unconformities towards it top and bottom. Another major unconformity divides this package into two separate unit marked by a red uneven line. (Droste and Van Steenwinkel, 2004; Vahrenkamp, 2013).

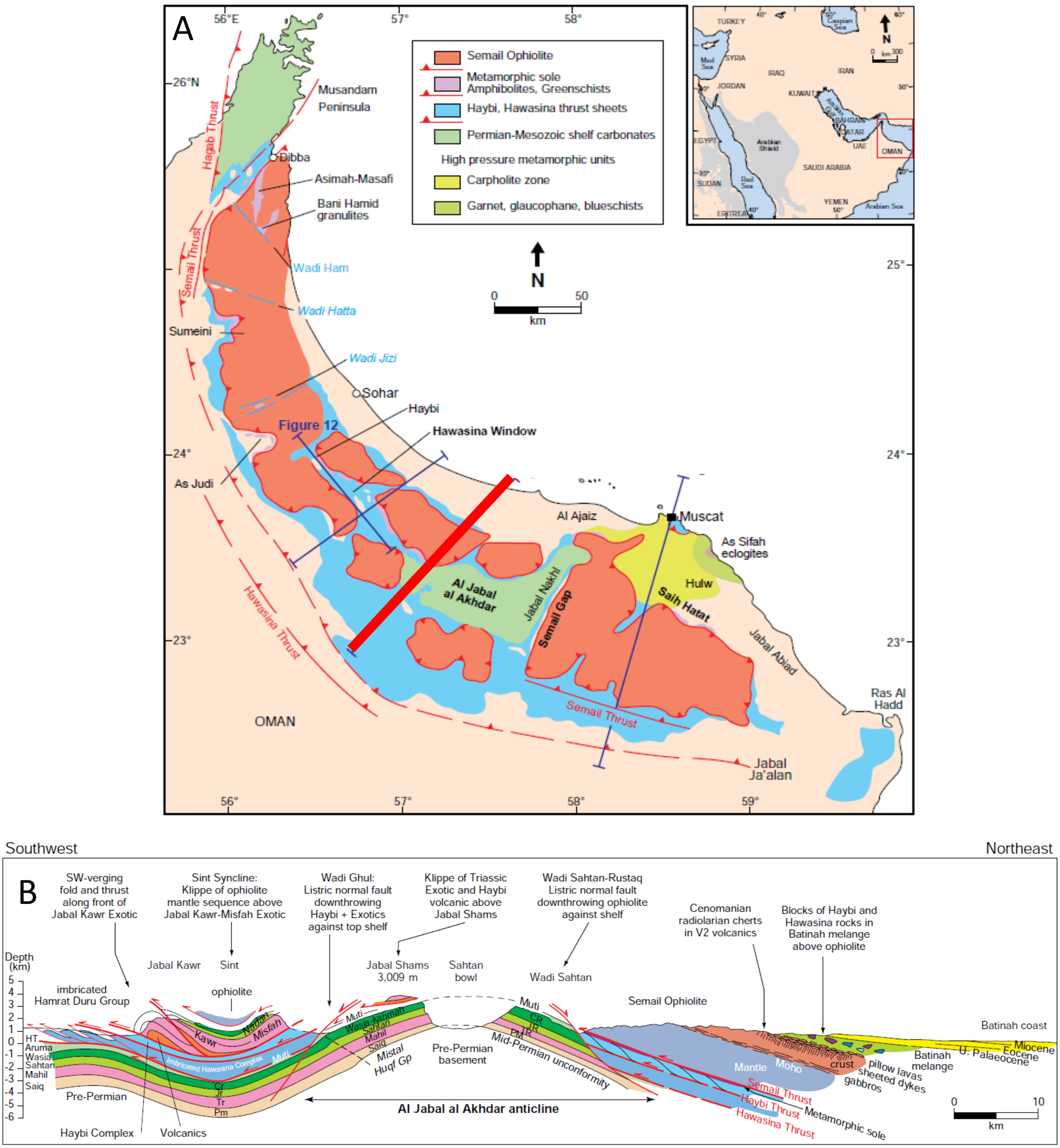


Figure A: Geological map of the Northeastern part of Oman, after Glennie et al. (1974) and Searle (2007).

Figure B: Locations of the cross-sections of the Hawasina Window, at Al Jabal al Akhdar marked in red line in figure A.

Wadi Mu'aidin

Wadi Mu'aidin exposes the rocks from uppermost part of the Sahtan group up until the base of Aruma Group (Muti Fm) representing more than 1 km of Cretaceous rocks. The entrance of the Wadi displays a massive anticline (part of Hawasina nappes) where rocks from the Jurassic age upto lower part of Cretaceous are exposed. The contact between the Upper Jurassic and Early Cretaceous rocks marks a major unconformity and the contact can be touched and studied in details as we drive into the wadi. At the mouth of the canyon the contact is represented by a conglomerate where the clasts are from the underlying older rocks.

This wadi exposes well Rayda Fm, Salil Fm, Habshan Fm, Lekhiwar Fm, Kharaib Fm, and Shu'aib Fm., Nahr Umr Fm, Natih Fm, and Muti Fm. As we drive into the wadi, the dip of the strata is such that we move into older and older rocks, until we hit younger rocks again. The contact between the two is a thrust fault which is separating the nappe on the top (lowest units Triassic/Jurassic turbidites) from the lower autochthonous strata (Muti Fm).

The rocks exposed along cliff's within the wadi show in general either resistant beds forming cliffs, or less resistant beds forming noses.

Entrance Wadi Mu'aidin

Observing a Major Unconformity in Rock Record

Wadi Nakhr

Wadi Nakhr is also famous as the Grand Canyon of Oman. It has a very narrow valley and the beds appear almost horizontal to sub-horizontal. The beds which were studied in this wadi were mostly from Salil upto Natih formation. As observed in the field as well in the photograph above, the hard/resistant beds make cliffs and low resistant beds make noses which are mostly argillaceous rich.

One of the most peculiar things observed in this wadi is geometry of the beds belonging to Salil-Habshan systems. Salil beds are observed pinching out towards south and thickening towards north indicating a clinoform geometry which is usually not identifiable using just core or well-log data. Seismic datasets do demonstrate clinoforms geometry, however, do not provide detailed information about the facies change within clinoforms (from proximal to distal). Therefore, these outcrops are the key tool for geologists and reservoir modelers to develop better understanding of the depositional system and their geometries, which is required to build better informed reservoir models.

The second point of focus in this wadi is Natih formation, which can be studied by driving south in the Wadi. Natih formation is divided into several members from A to G. In general within Natih formation three major T-R cycles (three sequences – from 1-3; bottom to top) have been identified. Sequence 1 and 3 are generally more thicker when compared to sequence 2. Sequence 3 within Wadi Nakhr displays beds deposited in an anoxic environment, which has been interpreted to represent an intrashelf basin fill.

Classroom!

Jabal Shams

Jabal Shams is very close to Wadi Nakhr and displays full suite of rocks from the middle Jurassic (along with Jurassic/Cretaceous unconformity), upto the Upper Cretaceous (Natih Fm). The total thickness of rocks visible is more than 1200 m. As observed in the previous wadi's, the cliff formers are the resistant units and the nose formers are the less resistant units.

Close look at the Natih formation displays an erosional surface at the top of Sequence 1. This surface is directly visible from the outcrop but would be difficult to identify from core or well-log data as the spacing between wells is usually more than that of the incision surface. These features might not be identifiable within seismic datasets unless the data is high-resolution. The identification of these surfaces is important to understand connected and disconnected units as sequence boundaries are potential flow barriers.

Walking within Natih fm on top of Jabal Shams, two very different facies were observed within the same bed. Between highs developed by rudists biostromes, trough cross stratified beds were observed which most likely represent sand waves. The facies change was sharp between the different facies, however, it would be very difficult to predict from well logs or cores due to well-spacing practices. Seismic data are not good enough to depict these changes.

Jabal Madmar represents part of Natih Formation and is very similar in structure, petrophysical properties, and stratigraphy to Fahud field (approx. 60 km away) and therefore provide a one to one co-relation. The rocks exposed at Jabal Madmar in general are interpreted to represent basin fill of an intrashelf basin showcasing planar bedded limestone (higher organic content facies) bioturbated/burrowed limestone (lower organic content facies), and oyster shell concentrations. Natih A and B were the topics of discussion at this location.

Jabal Madmar

Jabal Qusaibah represents upper part of Natih Formation. In general the facies are very similar to Jabal Madar showcasing bioturbated/burrowed limestone, planar bedded limestone, and oyster shell concentrations. At the top of Sequence 2 a sand wave complex was observed which was pinching towards northeast. Natih A, B, and C were the topics of discussion at this location.

The cause of formation of Intrashelf basin is still debated.

Jabal Qusaibah

Jabal Hedek....

The conclusion of the trip at the most distal part of the platform