Masila 1: Shallow shelf carbonate facies variability and secondary reservoir development - Saar Formation Masila block, Yemen

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ABSTRACT
Oil was discovered on the Masila block in 1991 with first commercial oil production starting in 1994. Most of the oil production has been from the Early Cretaceous Upper Qishn Formation. The Tawila field is the largest of the 15 existing fields on the Masila block. Over the past two years a greater emphasis has been placed on deeper secondary targets.

The Saar Formation in the Tawila Field is a 600 ft post-rift succession consisting of a series of shallow shelf carbonate sequences. The Tawila field is located on an isolated fault block structure within the NW-SE Sayun - al Masila Basin. Three reservoir facies have been identified within the uppermost portion of the Saar Formation: a) leached rudist biostromes, b) sucrosic tidal flat replacive dolomites, and c) leached bioclastic-peloidal grainstone shoals.

Multiple subaerial exposure events can be identified throughout the core by irregular contacts, shale-filled cavities, and karst-related breccias. Several of these exposure events are significant in the formation of secondary dissolution porosity. A mud-supported rudist floatstone biostrome forms a significant reservoir facies due to the creation of secondary micro and macro scale moldic and vuggy porosity related to an overlying exposure event.

Dolomitization also plays a key role in reservoir development. The early formation of dolomite immediately below the Valanginian Saar unconformity is associated with shallow restricted tidal flat sediments. Fine-grained sucrosic euhedral dolomite forms excellent intercrystalline porosity (20-25%) that is enhanced by subsequent dissolution of remaining allochems forming abundant molds.

Introduction

Hydrocarbons produced from Nexen's Masila Block 14 in Yemen (*Fig. 1*) were discovered in 1991 and by November 2002, 656 million barrels of oil had been produced, with estimated reserves of at least 1.1 billion barrels of oil. The Masila Block 14 is an irregular-shaped concession falling within a rectangle that is 36 by 51 km in size, covering 1250 km^2. Daily production currently averages 230,000 bopd from multiple zones. The primary oil producing interval is the Upper Qishn Formation (see Leckie and Rumpel, this volume). Production from secondary targets within the Lower Qishn, Upper Saar and Saar Formations began in early

2001 in the Tawila Field. Current secondary horizon production of 17,000 bopd represents roughly 18% of the total Tawila Field daily oil rate. All secondary horizons are currently under waterflood management. This core display summarizes the reservoir characteristics of the upper productive portion of the Saar Formation in the Tawila Field. The Saar Formation unconformablly underlies a sequence of mixed carbonate and clastic Upper Saar members. A detailed stratigraphic summary and synopsis of the regional setting of the Say'un – al Masila rift basin is presented by Leckie and Rumpel (2003).

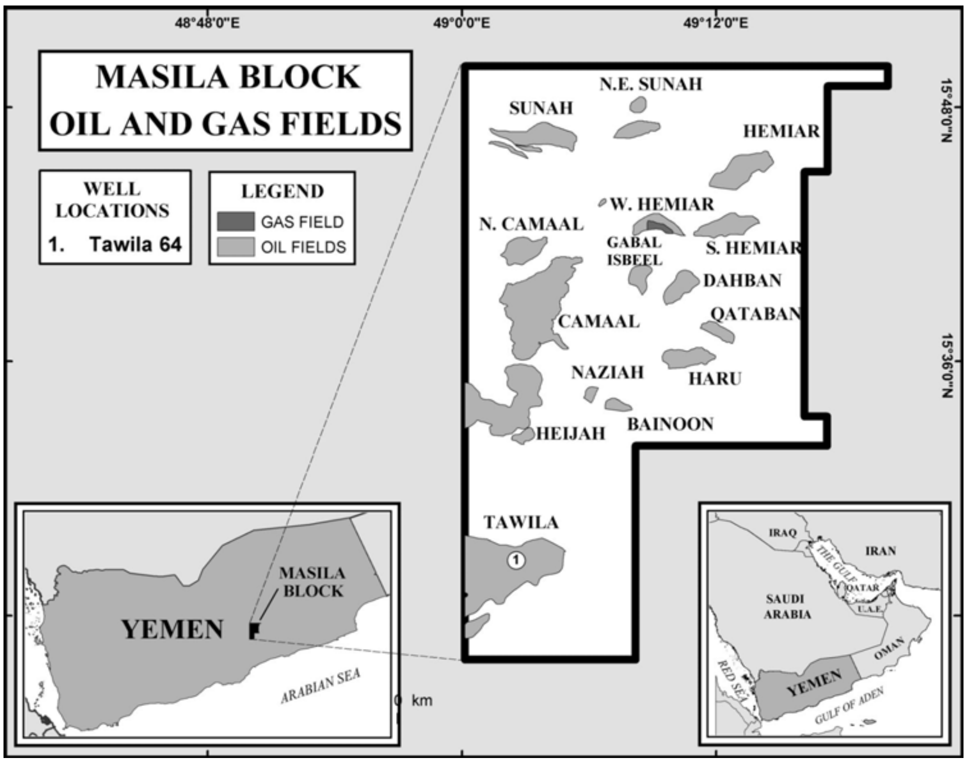


Fig. 1: Location map showing oil and gas fields of Masila Block 14 in the Republic of Yemen. Tawila-64 core location is highlighted in the southernmost field.

Saar Formation - Tawila Field

The Saar Formation in the Tawila Field is a 600 ft post-rift succession consisting of a series of shallow shelf carbonate sequences. The Tawila Field is located on an isolated fault block structure within the southern portion of the Masila Block. The structural complexity of the Tawila Field is relatively simple compared with other Masila Block Fields. *Fig. 3* illustrates a structure and net pay map of the Saar-C member in the Tawila Field. Hydrocarbons are trapped in several independent stratigraphic intervals within the upper 100 feet of the Saar Formation. *Fig. 4* illustrates the typical well log signature between two Saar producing wells on the crest of the Tawila structure (see *Fig. 3* for cross section location). Hydrocarbon bearing intervals have subtle increases in formation resisitivity compared with water producing zones.

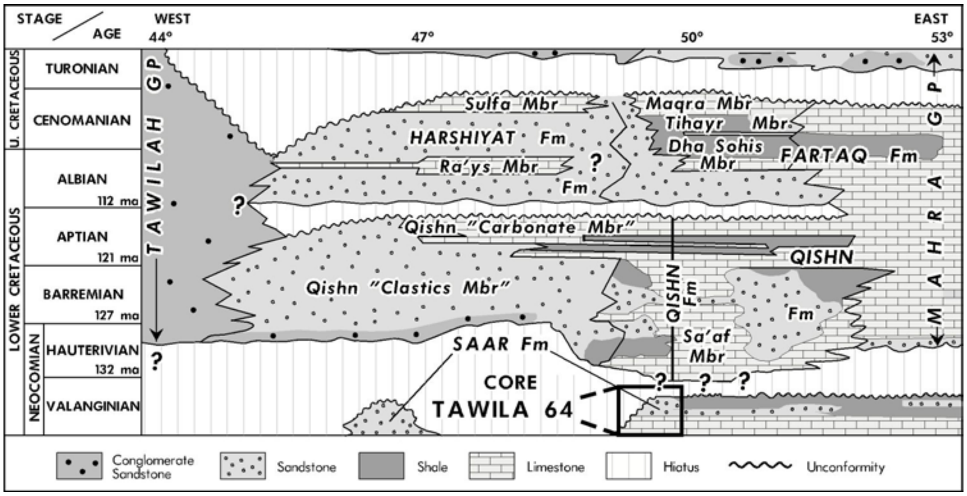


Fig. 2: Regional Lower Cretaceous stratigraphy in east-central Republic of Yemen (modified from Beydoun et al., 1998) showing the approximate stratigraphic position of the Tawila-64 core.

Tawila-64 Core

The Tawila-64 coring program consisted of one 120 ft core followed by a 60 ft core starting approximately 20 ft above the Saar Formation contact. The Tawila-64 core illustrates a series of shallow Lower Cretaceous carbonate environments.

Evidence for subaerial exposure

The Tawila-64 core illustrates many excellent examples of subaerial exposure surfaces. Several surfaces are associated with secondary porosity development and reservoir creation of underlying sediments. A series of exposure events across the lower 30 feet of core suggests multiple relative sea level fluctuations across a shallow carbonate shelf. Evidence for exposure consists of irregular contacts, shale-filled cavities, karst breccias and lag deposits.

Tawila Core Reservoir Facies Descriptions

The three reservoir facies that have been identified are: a) leached rudist biostromes, b) sucrosic tidal flat replacive dolomites, c) leached bioclastic-peloidal grainstone shoals.

Facies A: Leached Rudist Biostrome

The Saar-C member consists of 20-25 ft thick mud-supported rudist floatstones. An abundant assemblage of bioclastic material is present including gastropods, brachiopods and large rudists (2-3 cm). Well developed macro-scale moldic and vuggy secondary porosity is the defining reservoir characteristic. Subaerial exposure of overlying strata provided a mechanism for extensive leaching of large allochems. The reservoir porosity may be greater than 20% at the top of the reservoir but commonly decreases to less than 5% at the base. This decreasing porosity profile supports a subaerial leaching process for porosity creation. *Fig. 6A* indicates significant micro-scale secondary porosity within a mud-dominated matrix. This micro-scale porosity is a key requirement for development of effective reservoir permeability. Permeability in excess of 300 md has been measured associated with porosity greater than 25%. The pool average permeability is approximately 75 md. The mud-dominated rudist floatstones are believed to form biostromes deposited within relatively shallow low energy sub-tidal waters along a platform margin (*Fig. 7*).

Facies B: Sucrosic tidal flat replacive dolomites
Dolomitization played an important role in Saar Formation reservoir creation. Two significant dolostone reservoirs are observed in the Tawila-64 core. The first dolostone reservoir is a thin interval (1-2 ft) located above the Saar-C reservoir. The second interval is thicker and located directly below the Valanginian Saar unconformity. Both reservoirs have similar petrographic characteristics. Fine-grained sucrosic euhedral dolomite forms excellent intercrystalline porous (20-25%) reservoirs (*Fig. 6B*). Reservoir permeability can be in excess of 1000 md. Secondary dissolution of unstable aragonite allochems may enhance porosity by forming abundant molds. Parallel bedded sediments with fenestral porosity near the top of the Saar Formation is indicative of original tidal flat deposition. A thin shale bed approximately 10 ft below the top of the Saar Formation acted as a fluid barrier to downward migrating dolomitizing fluids originating from evaporating seawaters.

Facies C: Leached bioclastic-peloidal grainstone shoals
The third major Saar Formation reservoir consists of well-sorted oolitic-peloidal packstones to grainstones. Excellent interparticle porosity ranging from 15-20% is typical with associated permeabilties ranging up to 1000 md (*Fig. 6C*). An early fibrous radial calcite cement was important in preserving some primary interparticle porosity as little evidence of significant compaction was observed. These grainstone reservoirs were likely deposited in high energy shoals within a shallow subtidal shelf environment (*Fig. 7*).

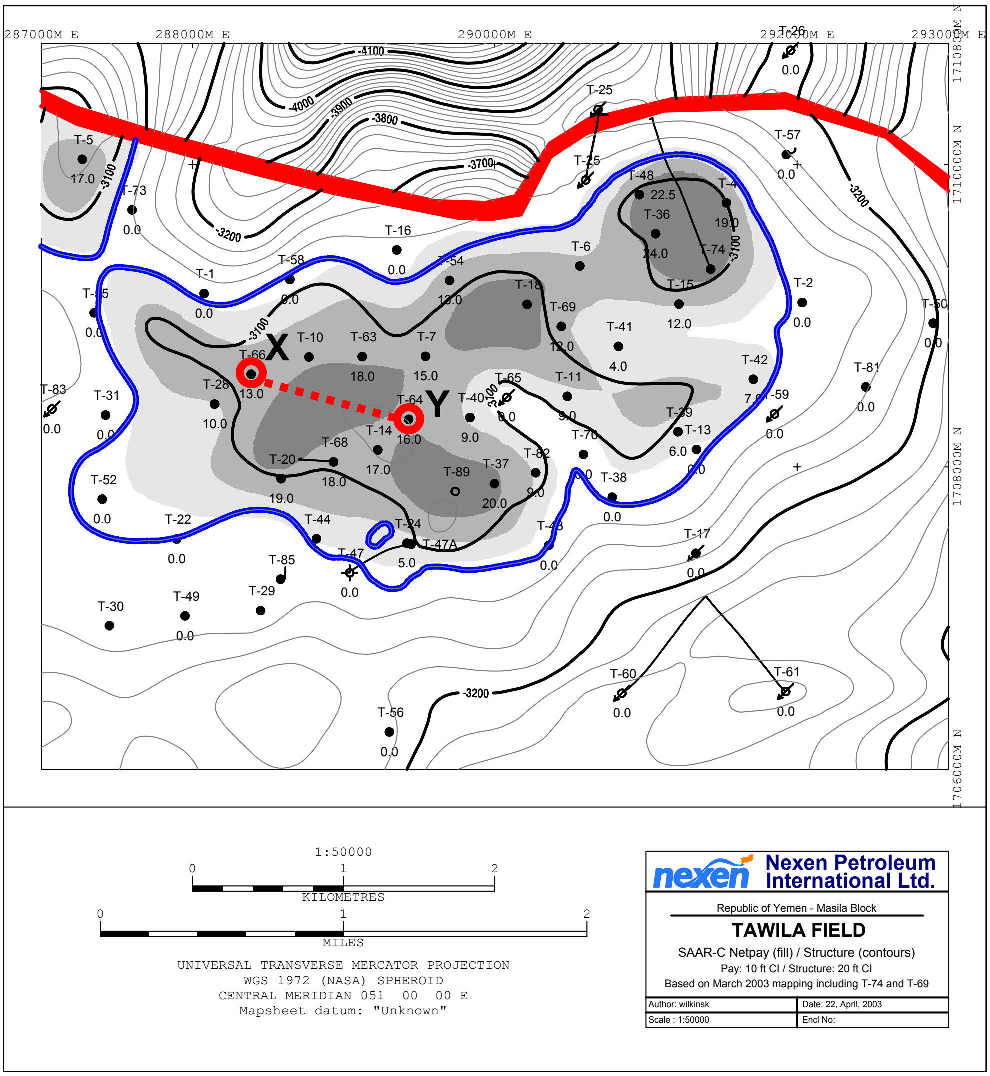


Fig. 3: Saar-C member structure (contours: 20 ft C.I.) and net pay (shade: 10 ft C.I.) map across the crestal portion of Tawila Field. The Tawila-64 core location and X-Y cross section (Fig. 4) are identified in the central portion of the field. The heavy contour represents the approximate oil-water contact at an elevation of –3121 ft subsea.

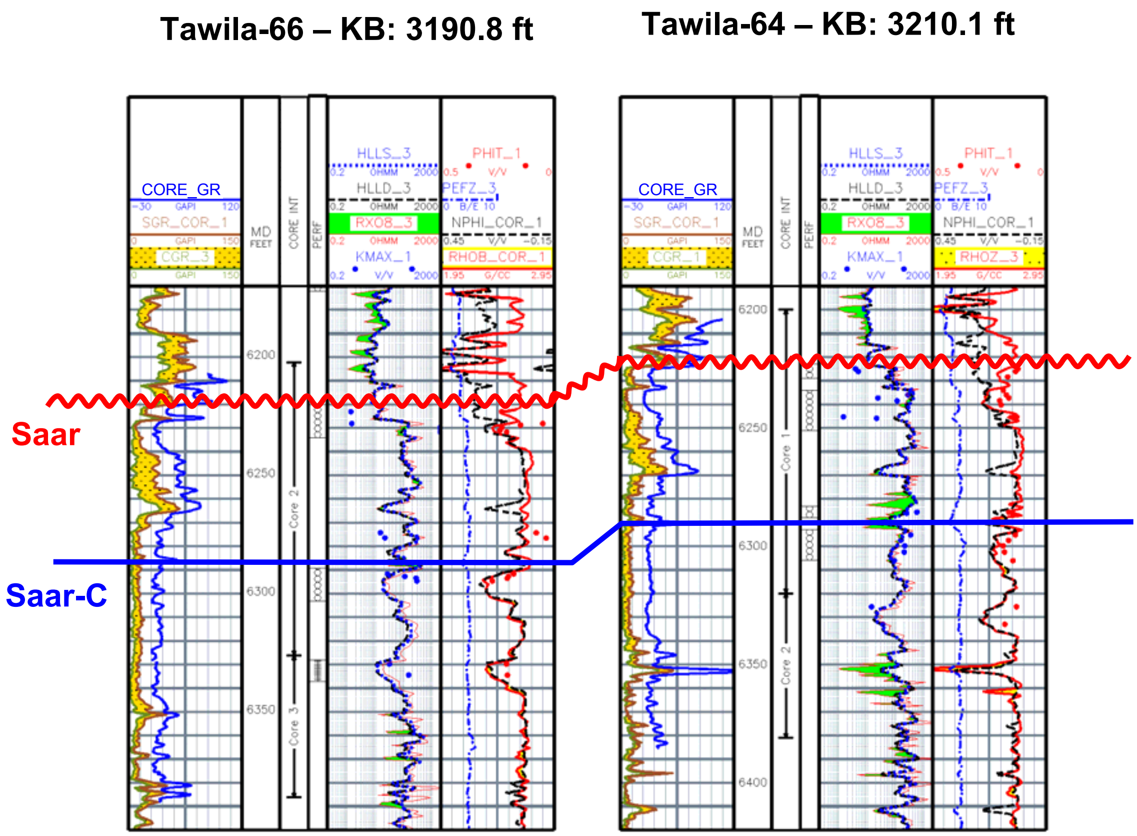
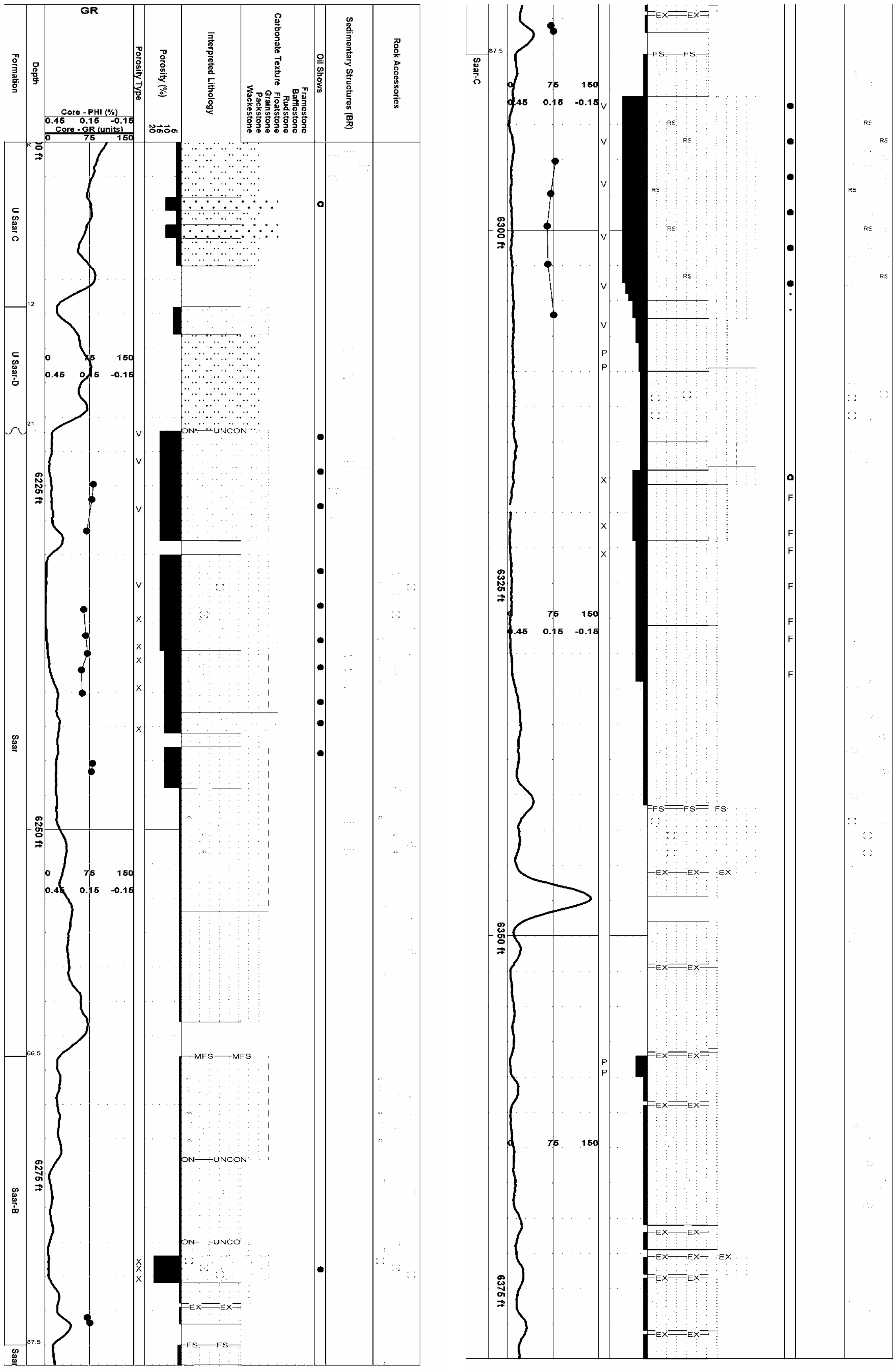


Fig. 4: Structural cross section X-Y. Two well cross section illustrating log characteristics of multiple Saar Formation pay intervals within the Tawila Field. Note subtle resistivity increase from water producing interval (plugged perforations - Tawila-66, 6335 ft) to hydrocarbon producing interval (Tawila-66 perforations at 6295 ft).

Fig. 5 (next page): Tawila-64 simplified core description. Productive reservoir is found within three main reservoir facies: a) leached rudist biostromes, b) sucrosic tidal flat replacive dolomites, c) leached bioclastic-peloidal grainstone shoals.



Formation
Depth
GR
Core - PHI (%)
0.45 0.15 -0.15
Core - GR (units)
0 75 150
Porosity Type
Porosity (%)
Interpreted Lithology
Carbonate Texture
Framestone
Bafflestone
Rudstone
Floatstone
Grainstone
Packstone
Wackestone
Oil Shows
Sedimentary Structures (BR)
Rock Accessories
U Saar C
U Saar-D
Saar
Saar-B
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6225 ft
6250 ft
6275 ft
6300 ft
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6350 ft
6375 ft
UNCON
MFS
EX
FS

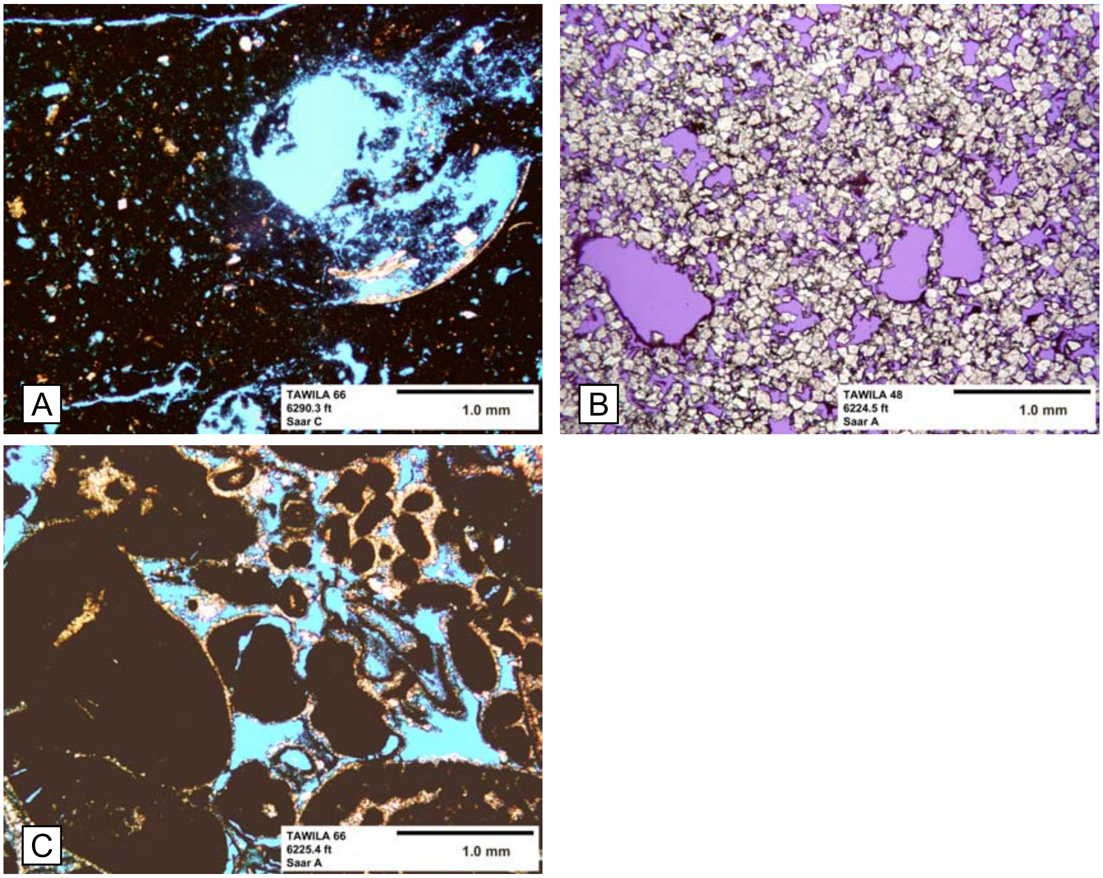

Fig. 6: Tawila Field Saar Formation thin section photomicrographs: A) Tawila-66 (6290.3 ft): Mud-supported rudist floatstone. Extensive development of micro and macro scale secondary porosity. B) Tawila-48 (6224.5 ft): Sucrosic tidal flat replacive dolomite. Extensive dolomitization resulted in an excellent intergranular porous and permeable reservoir facies (> 23% Ø, >1000 md). C) Tawila-66 (6225.4 ft): Leached bioclastic-peloidal grainstone shoals. High energy grainstone shoal facies with well developed interparticle porosity.

Conclusions

The Tawila-64 core presented in this paper illustrates a variety of shallow shelf carbonate environments. Reservoir intervals are found within both low energy and high energy paleo-environments. Secondary processes are essential for preservation and creation of reservoir quality intervals. Dissolution related to subaerial exposure and extensive dolomitization are important for Saar Formation reservoirs in the Tawila Field.

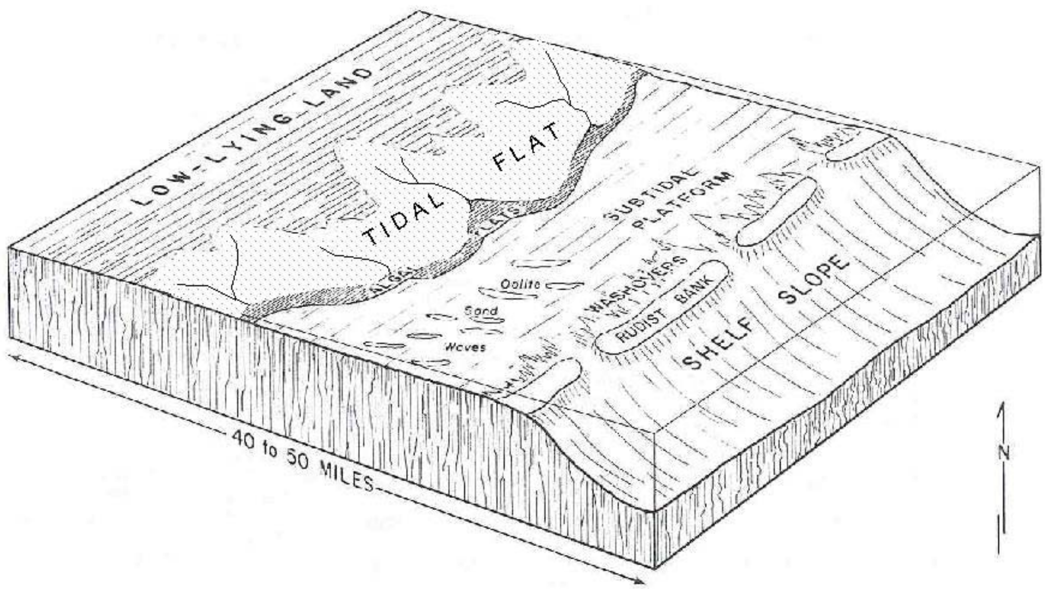

Fig. 7: A general paleo-environment model for the Saar Formation in the Tawila Field (modified from Bebout, 1977).

References

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