Sedimentology of Early Aptian Reservoir, Dunga Field, Kazakhstan*

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Abstract

Maersk, and partners Oman Oil and Partex, are actively developing the Dunga field, located 50 km north of the city of Aktau, on the Kazakh coast of the Caspian Sea. Oil and gas occur at a number of stratigraphic levels on the Dunga anticline, but development activity to date has focused on early Aptian sandstones.

The Dunga subsurface database includes 358 km^2 of 3D seismic, logs from 69 Soviet and partnership wells, and 226 meters of Aptian core. Characteristics of the Dunga deposits observed in core include: mud, silt and very fine-grained sand; organization of sand deposits into centimeter- to decimeter-scale beds, with muddy interbeds, which occasionally amalgamate into meter-scale sand intervals, where the best reservoir is located, pervasive soft-sediment deformation, common hummocky cross stratification, and frequent synaeresis cracks.

The trace fossil assemblage is variable in diversity, size and abundance. Cores immediately below and above the reservoir display a relatively diverse assemblage that includes abundant *Phycosiphon, Planolites, Helminthopsis, Chondrites, Zoophycus* and *Teichichnus*. In contrast, the intervening reservoir section shows a restricted trace fossil assemblage, with common *Planolites* and *Phycosiphon*, as well as frequent cryptic bioturbation. Traces in the reservoir section are stunted, and reflect a stressed environment with large salinity variations and high sediment input. Paleogeographic interpretations during the Aptian place the Dunga area within a broad embayed shelf, distant from large mountains. Analysis of the core data, and integration with log and 3D seismic data, suggests that the reservoir was deposited in a distal prodeltaic setting, on a storm-dominated shelf. Interpreted sediment transport processes included both hypopycnal and hyperpycnal flows downdip of the delta, as well as seaward return flows. Much of the sediment was subsequently reworked by shelf currents.

Aptian sandstones are immature ferroan calcite-cemented lithic arkoses, with moderate intergranular porosity (arithmetic mean = 16%). Horizontal permeability is low, with a geometric mean of approximately 1 mD. Cements are generally pervasive in originally higher-quality sandstones, but extensive in bioturbated sandstones, indicating that burrowing helped preserve original porosity.

Introduction

The Dunga field is located on the eastern coast of the Caspian Sea, in the South Mangyshlak basin of western Kazakhstan, about 50 km north of the city of Aktau (Figure 1). The field is unique, in that it is a Cretaceous oil reservoir in a province of mainly Jurassic oil and gas reservoirs. The largest of these Jurassic oil fields is Uzen, with recoverable reserves of 1.9 billion barrels (Carmalt & St. John, 1986).

The analysis presented here is based on an integrated ichnological, sedimentological and sequence stratigraphic study. This approach proved invaluable to identify key surfaces and facies. Much of the reservoir is comprised of interbedded and thinly bedded sandstones and mudstones that present complications for log analysis, geological modelling and well performance prediction.

Regional Geology

Basin setting

The Dunga field is located in the western portion of the South Mangyshlak basin, a distinct structural element within the much-larger Middle Caspian depression (Ulmishek, 2001). Most reservoirs in the South Mangyshlak basin are located in structural traps on the Zhetybay step, a northwest / southeast-trending regional culmination related to inversion of the basin during Miocene to Recent. Dunga field is found on the northwestern plunge of this structural complex.

Lower – Middle Jurassic sandstones are the principal reservoirs in the South Mangyshlak basin. An effective Upper Jurassic seal over much of the basin prevents vertical migration of hydrocarbons into younger rocks (Ulmishek, 2001). This Upper Jurassic seal is absent in the western portion of the basin, and oil and gas have migrated upward through this interval to the Cretaceous reservoirs in Dunga field.

Outcrop geology and implications

Aptian clastic rocks crop out in the Mangyshlak mountains, east of the Dunga field area (Figure 1). These outcrops are predominantly mudstones, with rare siltstone intervals, deposited in a transgressive marine shelf setting. As a result, samples of reservoir rocks in the Dunga area are known only from subsurface cores.

Paleogeography

Aptian paleogeographic maps based on subsurface and outcrop data place the Dunga area on a broad, partially embayed, marine shelf at the northeastern margin of the Tethys sea (Fedorenko and Miletenko, 2002; Scotese, 2000). The surrounding landmass was subdued, with low hills, and a lack of major river systems. Scotese (2000) interprets a 30° N, paratropical to arid paleoclimate for the area.

Dunga Stratigraphy

Dating approach and type log

Figure 2 shows the stratigraphic position of the Aptian reservoirs. The reservoir has been dated as Early Aptian based on unpublished proprietary palynological and micropaleontological analyses.

The mudstone intervals above and below the reservoir contain abundant and diverse microfauna, whereas the reservoir interval itself has an impoverished microfauna, but abundant spores and pollens. The reservoir interval thus records significant terrigenous input.

Sedimentology and Sequence Stratigraphy

Facies

Interpretations of Early Aptian sedimentology are based on detailed core descriptions, which have been integrated with log and 3D seismic data to build a three-dimensional reservoir framework over the entire Dunga area. On the basis of this core description, six sedimentary facies have been distinguished, including: Bioturbated Sandstone, Heterolithic Sandstone, Amalgamated Sandstone, Cemented Sandstone, Bioturbated Mudstone, and Fluidized Mudstone. Figure 3 is a series of core photographs showing principal sandstone facies.

Depositional Setting

Facies and sequence stratigraphic analysis indicates that the Early Aptian reservoir section in Dunga was deposited in a delta / shoreface complex. Distinct intervals record predominantly normal marine shoreface features, such as hummocky cross stratification in sandstones, diverse and robust bioturbation, with normal marine traces, and glauconite. In contrast, numerous interbedded intervals display deltaic signatures. These include soft-sediment deformation and contorted bedding, often with synaeresis cracks, fluidized mudstones that are the products of both hyperpycnal and hypopycnal flows, restricted and stunted trace fossil assemblages, as well as terrigenous plant material. A core photograph displaying examples of bedding styles, bioturbation and textures that reflect this mixed shoreface and deltaic environment is shown in Figure 4. Figure 5 is an interpretation of the Early Aptian depositional setting, as well as a satellite photograph of a modern analogue.

The interfingering nature of the delta and shoreface depositional systems records the complicated interplay between marine and fluvial processes, and neither process was entirely dominant. Nonetheless, vertical stacking patterns suggest trends in delta activity within an overall marine shoreface setting. The Early Aptian records two parasequence sets that may reflect the distal effects of delta progradation. These two parasequence sets are separated by a mudstone-prone heterolithic interval that may reflect either autocyclic processes, such as delta switching, or allocyclic response to base level rise. The top reservoir surface, with *Glossifungites* and overlying intensively bioturbated shoreface sandstones and mudstones, records delta abandonment in the Dunga area.

Dunga porosity, permeability and bioturbation

Early Aptian sandstones are mainly immature lithic arkoses. Principal framework grains are monocrystalline quartz, with common potassium feldspar, and plagioclase feldspars that show a range of alteration from fresh to partly leached. Lithic fragments are chert, volcanic rock fragments and phyllite metamorphic rock fragments. Varying amounts of detrital clays are present. Cements are principally ferroan calcite that in many cases, have reduced porosity to less than 10%. At these porosity levels, permeability is less than 0.1 md, and the rock is not effective reservoir.

Figure 6 shows close-up photographs of the core, along with thin section photomicrographs, and porosity and permeability data. The sandstones are of equivalent grain size, and occur within the same stratigraphic interval. The key control on the porosity and permeability appears to be the level of bioturbation. Cryptic bioturbation by meiofauna, along with bioturbation by macro-organisms, appears in many of the sandstones. Highest porosity and permeability appears where original bedding has been most disrupted by burrowing. Similar relationships between bioturbation and porosity preservation have been observed by Gordon, et al., (2010).

Summary

The Dunga field Early Aptian reservoir was deposited in a mixed shoreface – distal deltaic setting, in which repeated fluidized event beds, transported as both hyperpycnal and hypopycnal flows, were subsequently reworked by shoreface currents. Close integration of the ichnology and sedimentology of these deposits is vital to interpreting their origin.

References

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Website

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Figure 1. Location map for Dunga field.

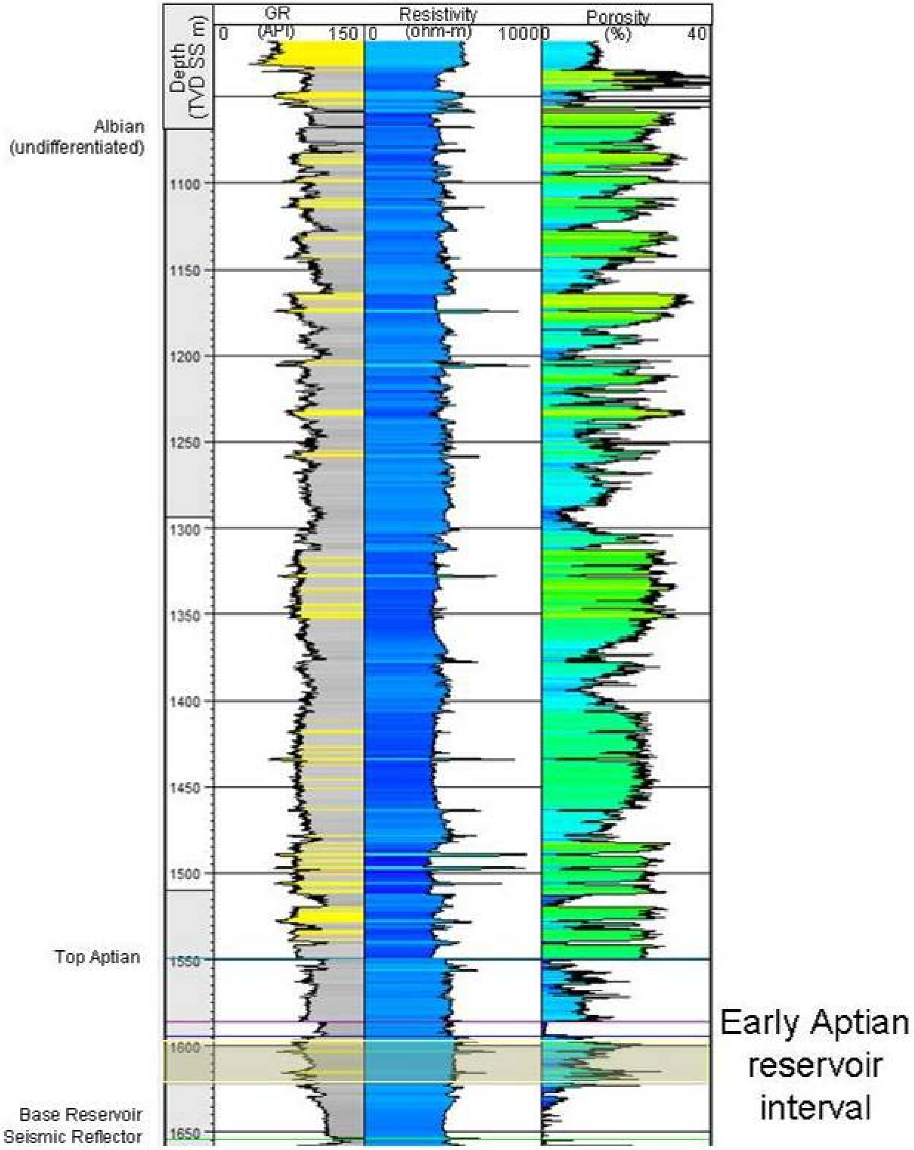
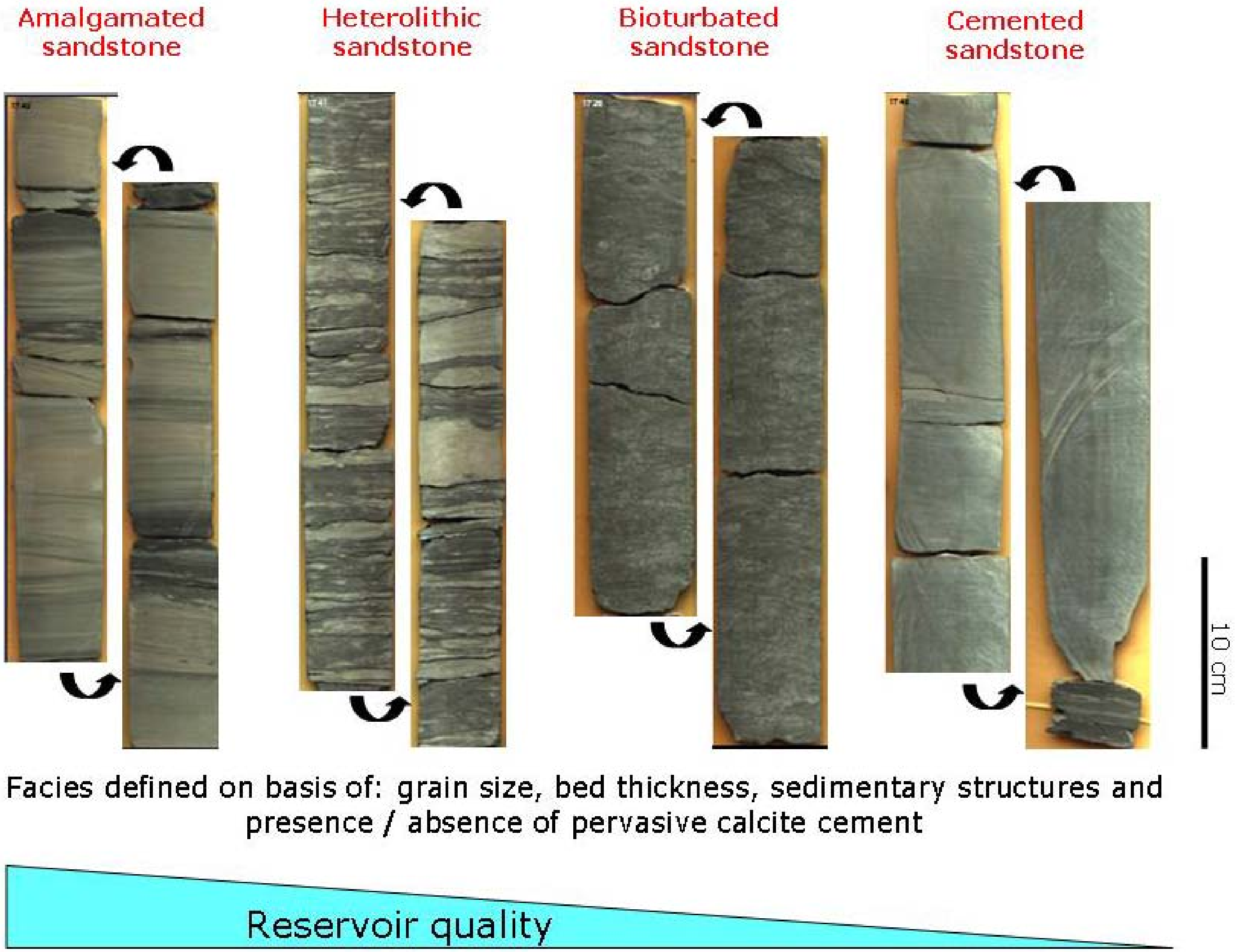


Figure 2. Type log for Dunga field.



Facies defined on basis of: grain size, bed thickness, sedimentary structures and presence / absence of pervasive calcite cement

Figure 3. Core photographs of sandstone sedimentary facies in Dunga reservoir.

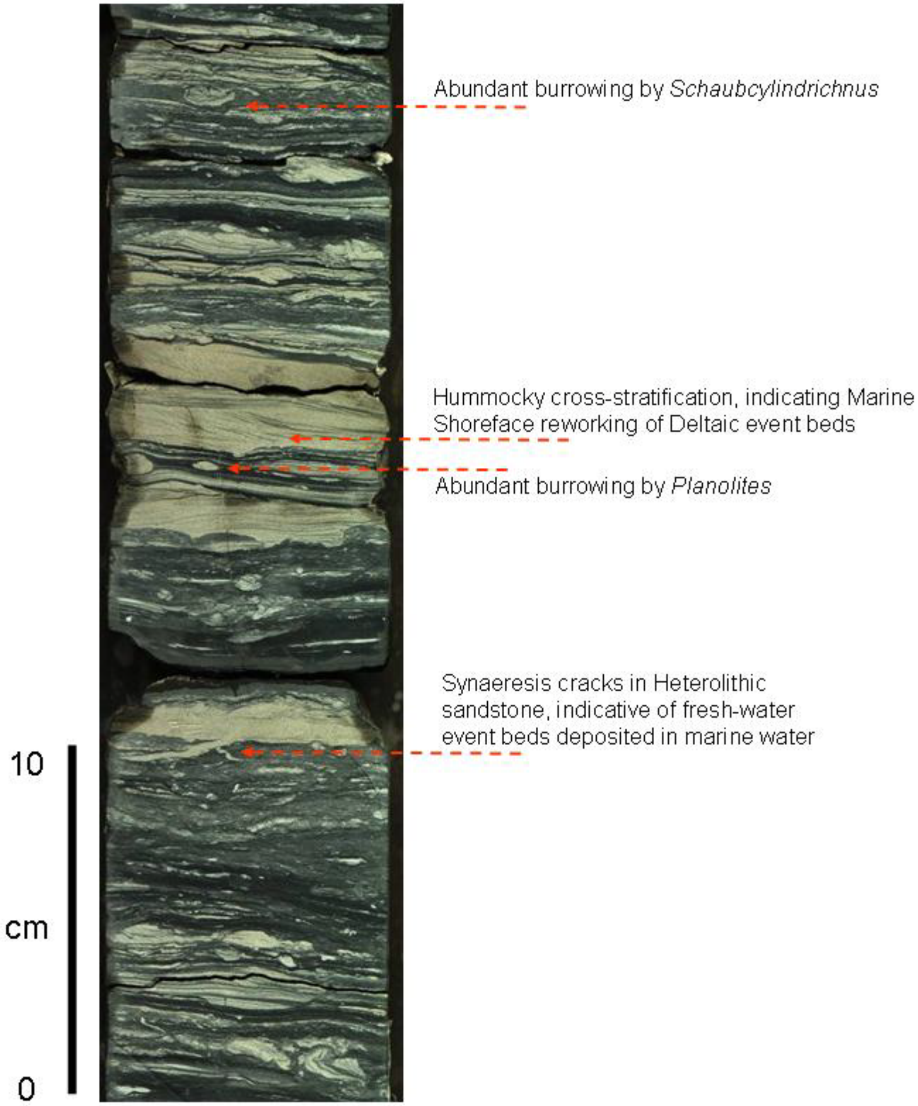


Figure 4. Core photograph of heterolithic sandstone facies. Note the bedding features that are diagnostic of marine shoreface (hummocky cross-stratification) and deltaic deposition from event beds (synaeresis cracks), which occur within a 10 cm interval of reservoir. Trace fossils are smaller than open marine forms, indicative of an environment stressed by salinity and turbidity variations.

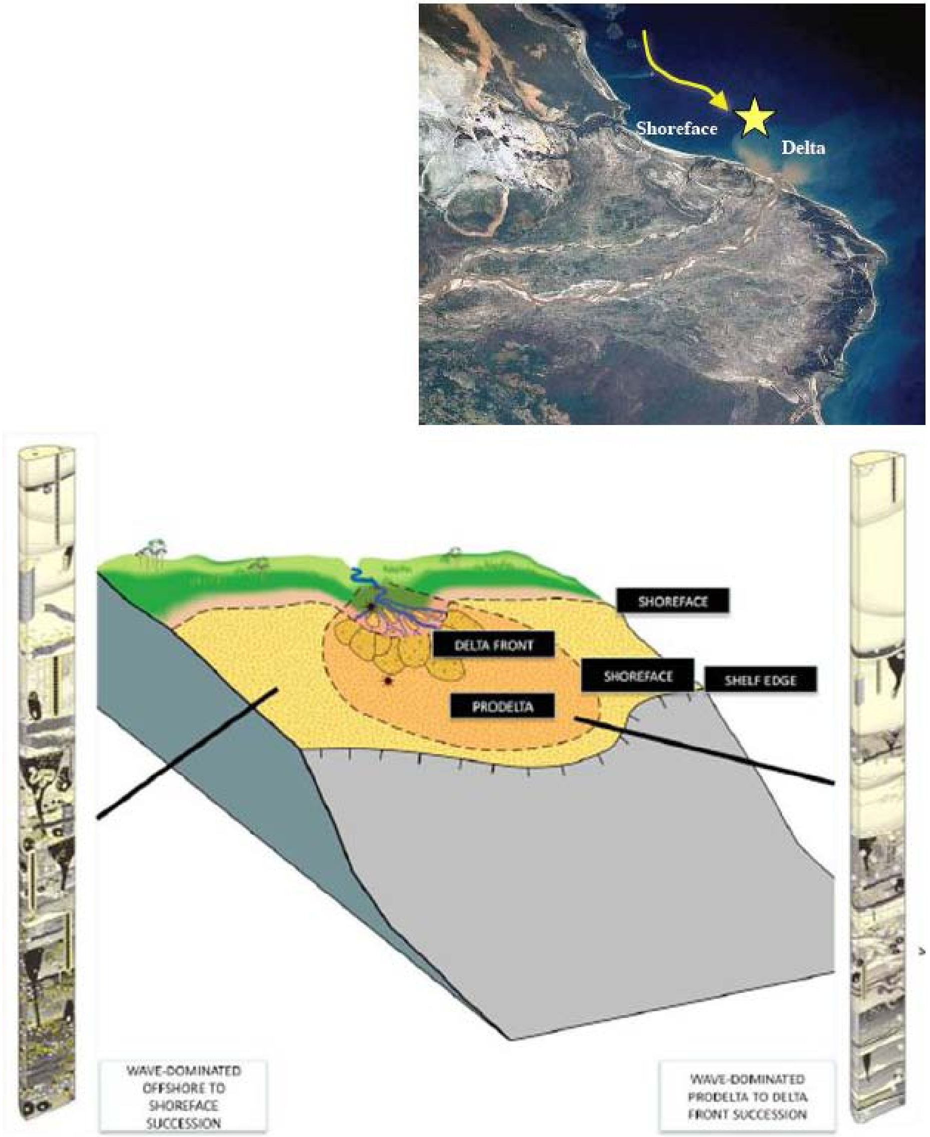
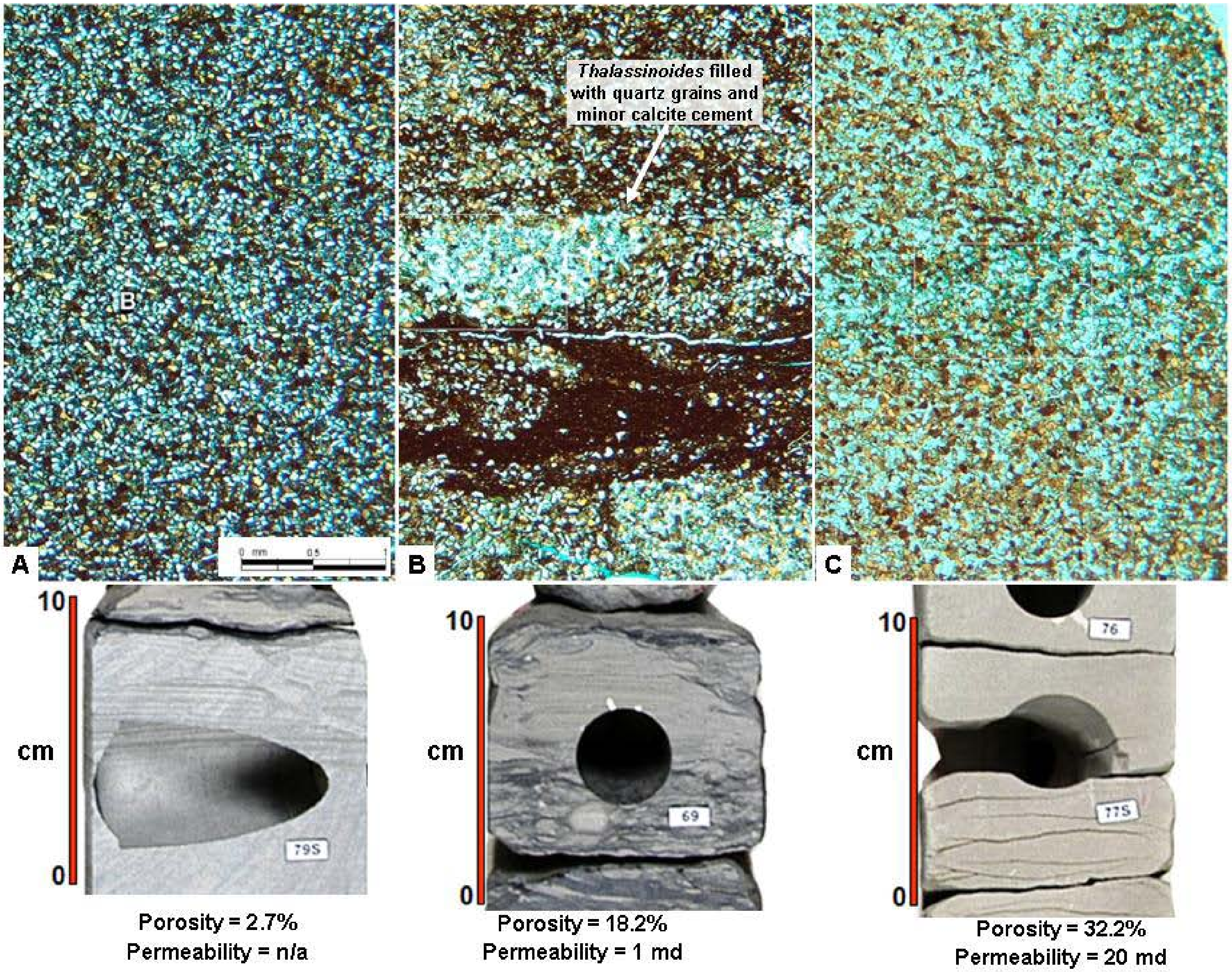


Figure 5. Depositional model and modern analogue for the Dunga Early Aptian reservoir. Modern shoreface/delta is Mangoky River Delta, Madagascar. Star indicates inferred location of Dunga-type reservoir, in a location influenced by a combination of shoreface and deltaic processes.



Porosity = 2.7%
Permeability = n/a

Porosity = 18.2%
Permeability = 1 md

Porosity = 32.2%
Permeability = 20 md

Figure 6. Thin section photomicrographs and core photographs of Dunga early Aptian sandstones. All photographs and photomicrographs are at same scale, and all samples are located within a one-meter interval of reservoir. Activity by burrowing organisms appears to have improved reservoir quality by mechanically sorting grains by mineralogy, as well as by coating grains with chemicals that may have retarded calcite cementation. Bedding is observed in the core in A, has been moderately reworked by burrowing in B, and has been completely churned in C.