# Sedimentary Evolution and Reservoir Prospective of Bashkirian-Moscovian Mixed Siliciclastic-Carbonate Deposits in the Loppa High (Norwegian Barents Sea)*

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## Abstract

The Loppa High, in the Norwegian Barents Sea, is a buried isolated structural feature. The sedimentary evolution of the Bashkirian-Moscovian sequence shows, in addition to eustatism, the effects of local to regional tectonic starting from the Late Carboniferous. This study has investigated a core section (283 m thick) characterized by Late Bashkirian conglomerate-dominated marine to continental deposits, which develop upwards to cyclically interbedded marine siliciclastics and subtidal carbonates. The upper interval is exclusively dominated by Early Moscovian peritidal carbonates of the Gipsdalen Group, considered a major reservoir-prone unit of the Upper Paleozoic of the Barents Sea. On the other hand, the Bashkirian-Moscovian units of the reservoir-prone Gipsdalen Group have received little interest in the Barents Sea region, and even less on the Loppa High.

This study has been focused in a first step on the identification of the main features such as lithology, texture, visible porosity and permeability, sedimentary structures and biotic content. Eight Lithofacies Associations (LAs) have been then identified, and have provided the basis to define depositional facies models that reflect the environmental evolution of the complex Loppa High system through time. Metric to decametric shallowing- and deepening- upward trends have been individuated, superimposed on a 3rd order Bashkirian to Early Moscovian transgressive depositional trend, also recognizable in other areas of the western Barents Sea. The post-depositional history of the section reveals a strong diagenetical overprint mainly affecting the carbonates deposits through different phases of extensive dolomitization and silicification. The analysis of measured porosity and permeability trends of the carbonate

sediments across the section and through cross-plots shows that the two parameters are mostly independent by facies variations across the section. This allows developing preliminary conclusions about a potential strong control of post-depositional processes on the reservoir potential of these rocks.

## Introduction

The Loppa High is a buried isolated structural feature placed in the southern Norwegian Barents Sea (Figure 1). It is (southward and westward) separated from the Hammerfest, the Tromsø and the Bjørnøya Basins by fault complexes. To the East, it gently grades into the Bjarmeland Platform (Stemmerik et al., 1999). During its geological history this eastward tilted block underwent several phases of uplift, subsidence and erosion (Larssen et al., 2002), leading to an overall complex syn- and post-depositional development (Figure 1). The High evolved as an easterly dipping depositional system starting from the late Bashkirian. At that time it was characterized by the deposition of the Gipsdalen Group (Figure 1), considered as major reservoir prone Unit of the Upper Paleozoic sediments of the Barents Sea. Continental to shallow marine Bashkirian siliciclastics were stepwise drowned starting from the Early Moscovian, following a regional transgressive depositional trend also recognized in other areas of the western Barents Sea, Spitsbergen, Bjørnøya and North Greenland (Lønøy, 1995; Stemmerik et al, 1998; Eliassen and Talbot, 2003a; Stemmerik and Worsley, 2005). This led to the deposition of mixed carbonate-siliciclastic deposits in the proximal part of the Loppa High whereas carbonates dominated the distal areas. The well 7120/2-1 was drilled in the southern part of the Loppa High, close to the crest of the structure (Figure 1). Parts of the conventional cores were taken starting from 1960 m to a depth of 2243 m (MD) (cores no. 18-1), corresponding to the Upper Bashkirian-Upper Moscovian segment of the sequence. For this study the latter interval has been investigated, in order to better assess the evolution of the Loppa High as deposystem at that time, and give a preliminary evaluation of the reservoir potential of the lower Gipsdalen Group carbonate units.

## Methods

At this stage of the study212 meters of cores were logged and described at decimetric to metric scale, mainly depending on the quality of the cut, using a 9X Zeiss hand-lens. The description was based on the identification of the main depositional features as lithology, texture, sedimentary structures, biotic content, shallowing/deepening upward trends, visible/measured porosity and permeability. The sedimentological description has been integrated with available petrophysical data as Horizontal Porosity (HPOR %) and Horizontal Permeability (HKA mD).

## Lithofacies Associations and Depositional Evolution

The studied section was divided in three main lithostratigraphic intervals and eight Lithofacies Associations (LA) have been identified across the sequence.

Conglomeratic interval

It covers the lower part of the studied sequence and is represented by conglomerates, alternated with less sandstone and siltstone layers. Bashkirian-Moscovian conglomerate deposits have also been described from the Kapp Kare Fm. and the Landnørdingsvika on Bjørnøya (Stemmerik et al., 1998). The following Lithofacies Associations (LA) have been detected (Figure 4):

LAC1: Matrix supported polymict conglomerates
LAC2: Clast-supported fine conglomerates

The matrix supported conglomerates of the LAC1 have been considered as subaqueous debris flows, probably deposited on the slope of the prograding coarse-grained fan delta. The fine conglomerates and the pebbly sandstones of the LAC2 can been interpreted as subaerial sheet flood and delta plain deposits. Overall low porosity and permeability characterize the LAs of the conglomerate interval and no visible oil shows have been detected.

Siliciclastic-carbonate interval

It covers the middle part of the studied section and shows alternations of sandstones, siltstones, less pebbly sandstones and conglomerates with peritidal carbonates (Figure 2). The alternation between different lithotypes is sometimes very sharp and corresponds to erosional surfaces, but several intervals show indistinct contacts. The following clastic LA have been detected (Figure 4):

LAS1: Sorted coarse sandstones and fine conglomerates (pebbles-dominated)
LAS2: Fine laminated sandstones
LAS3: Laminated siltstones

The clastic deposits of the siliciclastic-carbonate interval can be interpreted as belonging to a fan-delta complex. The overall grain size and the sedimentological structures of the LAS1, suggest an upper delta front depositional environment whereas pro-delta environment settings are suggested for the sediments of the LAS2. The LAS3 siltstones could represent the more distal and/or deep pro-delta environment, with the wave influence absent or very limited. Even though the LAS1 shows porosity peaks of 13.8%, the measured permeability of the whole clastic sequence is very low (up to 1.00 mD) and no visible oil shows have been detected. The carbonate sediments (described below) of the siliciclastic-carbonate interval mark the beginning of mixed siliciclastic-carbonate sedimentation in the Loppa High area.

Carbonate interval

It iss dominated by peritidal partially or completely dolomitized carbonate deposits. The extensive dolomitization and silicification processes these carbonates have undergone, often do not allow a precise definition of primary textures and biotic content. However, the following LA has been recognized (Figure 4):

LAD1: Dolomites, dolomitized mudstone and laminites
LAD2: Dolomitized bioclastic packstone-grainstone
LAD3: Dolomitized bioclastic wackestone

LAD1 has been interpreted as deposited within intertidal restricted lagoonal settings, occasionally hypersaline and cyclically emerged. These particular settings do not differ from other Moscovian proximal marine depositional environments recognized on structural isolated highs and land-attached platforms of the Northern Pangaea shelf (Lønøy, 1995; Stemmerik et al., 1999; Eliassen and Talbot, 2003a). The LAD2 reflects a higher biological diversity and major hydrodynamism acting on sediment reworking. We interpreted these sediments as shallow subtidal bars/shoals, which undergo the wave action and are regularly interdigitated with the muddy sediments of the LAD3. The latter have been interpreted as deposited in a subtidal lagoonal environment, with normal to restricted water circulation and oxygenation, testified by the minor biological diversity. In general, the interpretation of the three carbonate LAs allows to consider the Moscovian carbonates sediments of the well 7120/2-1 as deposited in an inner ramp environment, ranging from subtidal to supratidal lagoonal/sabkha settings (Figure 3).

## Discussion and Conclusions

Eustatism and local to regional tectonic affected the Loppa High starting from the Late Carboniferous (Stemmerik et al., 1998). The deposition of the conglomerate-dominated marine to continental deposits in the Late Bashkirian develops upwards to cyclically interbedded marine siliciclastics and carbonates and evolves then to pure peritidal carbonate sedimentation. The performed sedimentological study from the well 7120/2-1 allowed to detect eight Lithofacies Associations and to define three main lithostratigraphic intervals, reflecting the Late Bashkirian-Early Moscovian depositional evolution of the Loppa High (conglomeratic, siliciclastic-carbonate and carbonate intervals.) Moreover, palaeoenvironmental facies models for each lithostratigraphic interval have been created, in order to suggest a possible evolution of the Loppa High from a clastic fan-delta dominated to a peritidal inner ramp lagoonal environment. The observed upward increasing of carbonates reflect the onset of the 3rd order Late Bashkirian-Early Moscovian transgressive depositional trend, recognizable in other areas of the western Barents Sea (Larssen et al., 2002; Stemmerik and Worsley, 2005). It is plausible that the deposition of the carbonate strata among the siliciclastics is favoured by short periods of "delta abandonment", strictly related to decreasing continental runoff during stages of reduced tectonic uplift on the High. The core observation reveals a complicated post-depositional history, expressed by a strong diagenetical overprint mainly affecting the carbonates deposits through probable different phases of dolomitization and silicification. Cross-plots of measured Porosity (CPOR %) vs. Permeability (HKA mD) for the carbonate LA show the two parameters are independent by facies variations across the section. We suggest that the diagenetical overprint could be considered as the main factor controlling the reservoir features of the Upper Moscovian carbonate sediments of the Loppa High. This results in interesting implications about further assessments of the lower part of the Gipsdalen Group most "promising" reservoir prone Unit of the Upper Paleozoic Barents Sea sediments.

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## References

Eliassen, A., and M.R. Talbot, 2003a. Sedimentary facies and depositional history of the mid Carboniferous Minkinfjellet Formation, Central Spitsbergen, Svalbard: Norwegian Journal of Geology, v. 83, p. 299-318.

Larssen, G.B., G. Elvebakk, L.B. Henriksen, S-E. Kristensen, I. Nilsson, T.J. Samuelsberg, T.A. Svana, L. Stemmerik, and D. Worsley, 2002, Upper Paleozoic lithostratigraphy of the Southern Norwegian Barents Sea: Norwegian Petroleum Directorate Bulleltin v. 9, 259 p.

Lønøy, A., 1995, A Mid-Carboniferous, carbonate-dominated platform, Central Spitsbergen: Norsk Geologisk Tidsskift, v. 75, p. 48-63.

Stemmerik, L., E. Elvebakk, I. Nilsson, and S. Olaussen, 1998, Comparison of upper Bashkirian–upper Moscovian high frequency sequences between Bjørnøya and the Loppa High, western Barents Sea: *in* K.O. Sandvik, F.M. Gradstein, and N.J. Milton, (eds), Sequence Stratigraphy: Norwegian Petroleum Society (NPF) Special Publication 8, Elsevier, Amsterdam, p. 215–227.

Stemmerik, L., G. Elvebakk, and D. Worsley, 1999, Upper Palaeozoic carbonate reservoirs on the Norwegian Arctic Shelf: delineation of reservoir models with application to the Loppa High: Petroleum Geoscience, v. 5, p. 173-187.

Stemmerik, L., and D. Worsley, 2005, 30 years on - Arctic Upper Palaeozoic stratigraphy, depositional evolution and hydrocarbon prospectivity: Norwegian Journal of Geology v. 85, p. 151-168.

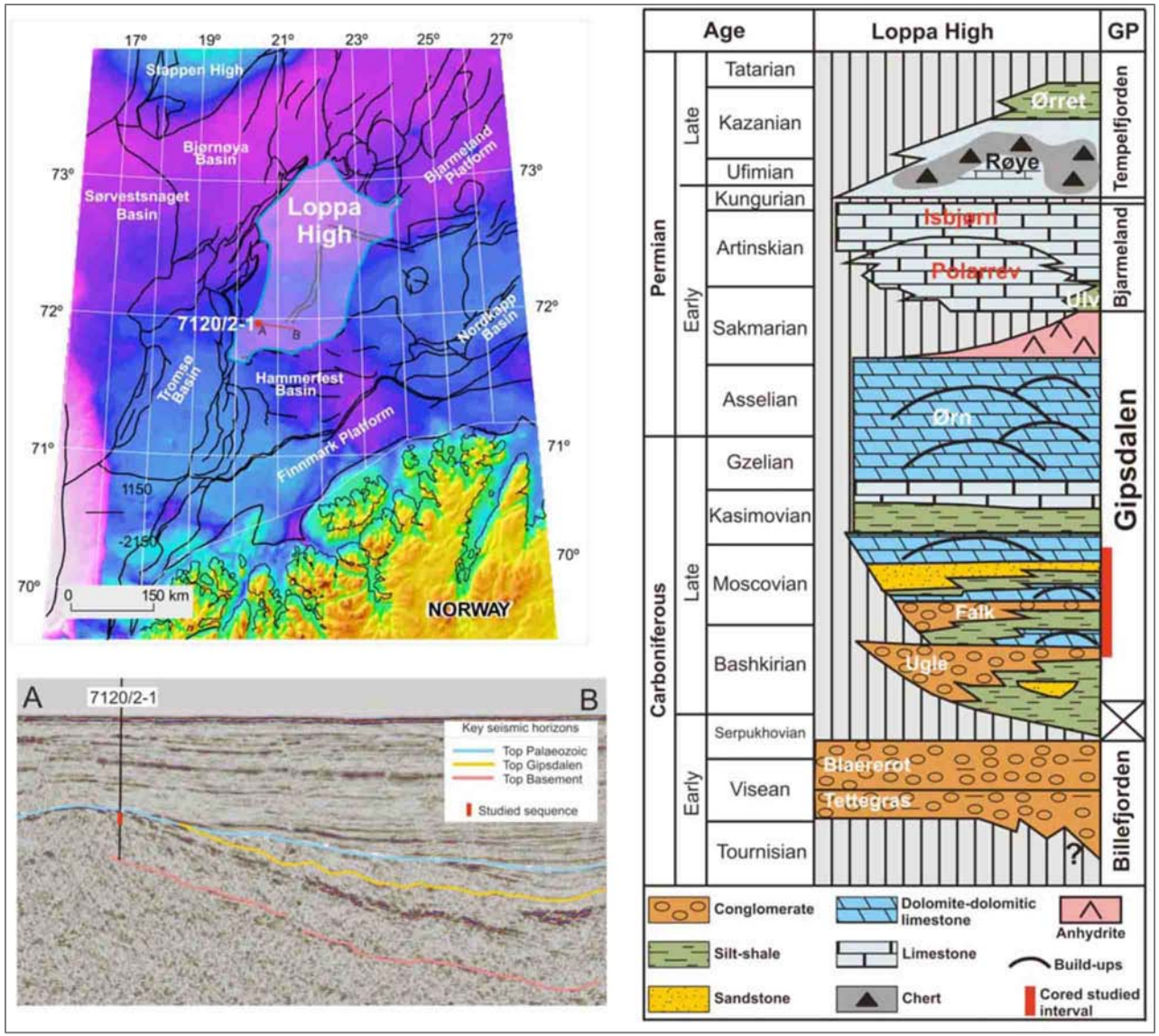


Figure 1. Upper left: bathymetric map of the southern Norwegian Barents Sea, major structural lineaments and Basins. The blue-bordered area corresponds to the Loppa High structural feature, with the position of the well 7120/2-1. Bottom left: seismic profile of the easterly tilted Loppa High, showing the proximal position (close to the crest of the structure) of the well 7120/2-1 and the reflectors covered by the studied cores. Right: schematic log of the Upper Paleozoic lithostratigraphy of the Loppa High (modified from Larssen et al., 2002).

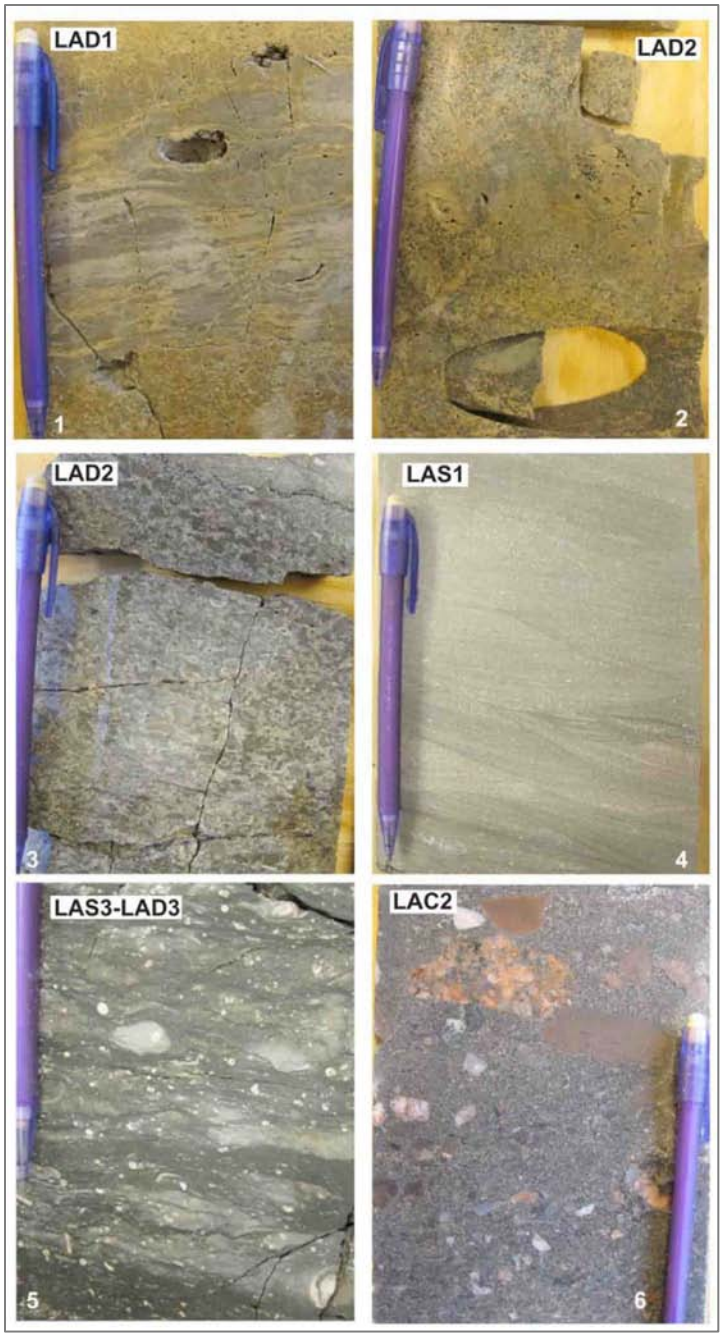


Figure 2. Stratigraphic log of the upper part of the siliciclastic-carbonate interval: main lithological, sedimentological, diagenetic and petrophysical features. See the legend for explanation of the symbols.

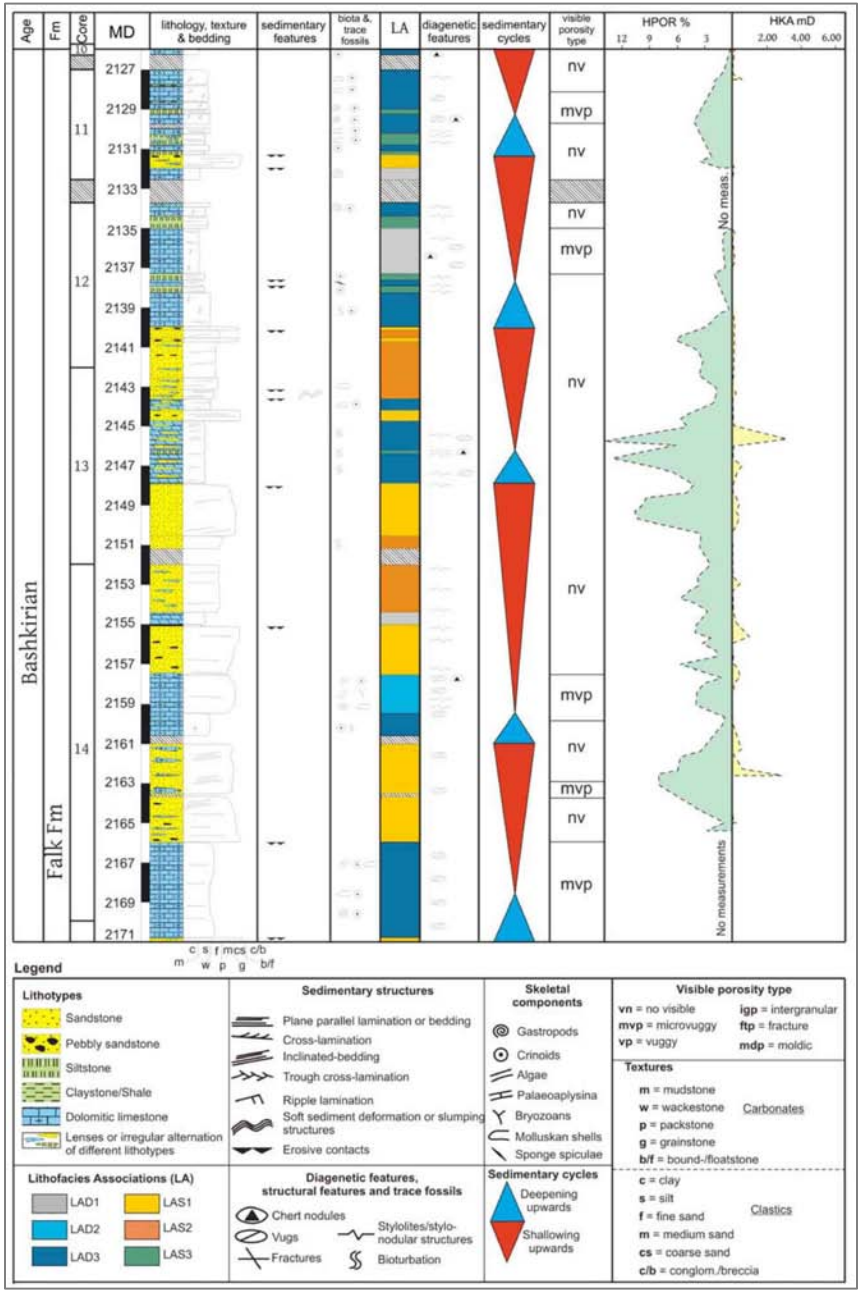


Figure 3. Schematic palaeoenvironmental model for the carbonate interval and hypothetical position of the three LAs.

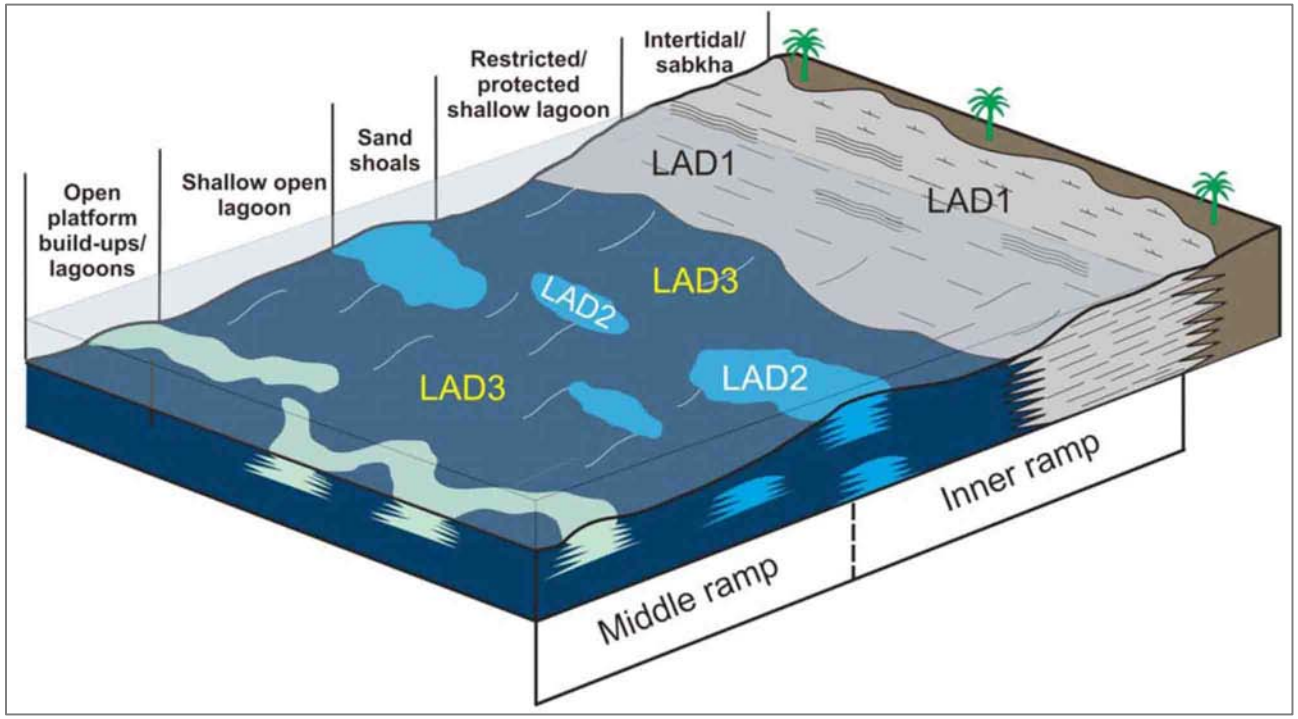


Figure 4. Some LA identified across the studied section. 1: dolomitized microbial laminites of the LAD1; note trapped gastropods and molluscan shells. 2: dolomitized and silicified Bryozoan-dominated grainstones of the LAD2; note the presence of strong oil residuals within vugs and molds. 3: bryozoan grainstone of the LAD2 with no oil residuals. 4: spectacular trough cross-lamination of the LAD2 coarse sandstones. 5: Nodular interdigitation between irregular lenses of dolomitic wackstone with crinoids and molluscan shells (LAD3) and siltstones of the LAS3. 6: fine orthoconglomerates of the LAC2.