PS Seismic Characterization of a Calciclastic Submarine Fan in the Cenozoic Foredeep of the Oman Mountains*

Luca Fava[1]

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[1]OMV East Exploration GmbH, UAE, Abu Dhabi (Luca.Fava@omv.com)

Abstract

Carbonate turbidites are much less studied and known of their clastic counterpart. Only recently (Payros and Pujalte, 2008) some attention has been dedicated to the Calciclastic Submarine Fans (CSF). Few discoveries have been made in these sediments in the Middle East, and particularly in the Oman Mountains foredeep basin, they represent well known potential reservoir horizons (Hertig et al., 1995). Despite this, little attention has been so far dedicated by the Oil industry to these deposits, because of the issues with reservoir quality. Thus, 3D seismic examples of these possible reservoirs are not available in UAE and, as per author knowledge, in the literature regarding Middle East basins.

ADNOC and OMV have recently acquired a 3D seismic survey in the area NW of Al Ain (Granser et al., 2015) covering the southern end of the Pabdeh foredeep. The survey is large enough to image the margin of the foredeep on three sides (West, South and East). This new seismic data provide a good basis for the detailed interpretation within the foredeep basin and consequently, for the needed seismic characterization of CSF.

This study aims at defining in detail a CSF through the interpretation of a 3D seismic survey for the first time in UAE. Detailed horizon picking of different seismic cubes (PSTM and RAI) and seismic attribute extractions are the main tools to define geometry, architectural elements and depositional environments of the turbidite system.

The Cenozoic (Pabdeh) foredeep of the UAE developed as a result of loading in front of the Oman Mountains thrust-and-fold belt verging to the West. Subsidence started during the Middle Eocene (Rus Fm.). A thick Eocene and Oligocene succession infilled the basin with shallow marine carbonates at the margins and shales and resedimented carbonates (calciturbidites) at the depocenter. By the end of the Oligocene the basin was closed. Subsequent deposits are represented by alternations of evaporates and continental-derived clastics (the Miocene lower Fars Fm.). The Late Miocene tectonic phase partially involved the infilling of the foredeep, in the Eastern area of the basin. Unfortunately, the lack of velocity information in the only available well within the 3D survey outline prevented a precise calibration of the interpreted seismic horizon

into a semi-regional chronostratigraphic framework. In spite of this limitation, a relative chronostratigraphy and a basin evolution defined by major depositional-structural events can be built with confidence based on the seismic interpretation.

A clear karstified surface has been interpreted on the western side of the 3D seismic survey. This surface is affected by a series of normal faults running north-south with the hanging wall block to the east slipped down and the western block affected by the subaerial exposure. The interpreted CSF seems to have been formed along the faults with a NNW-SSE direction toward the foredeep depocenter. The system presents a main feeder channel showing erosive features in seismic, a channel mouth at the slope break and laterally defined by faults and a depositional lobe clearly defined by seismic attribute extractions (RMS amplitude and Swetness).

The mapped SCF shows striking similarities in term of size, environments and architectural elements, not only with the depositional model for a medium-size CSF as depicted by Payros and Pujalte (2008), but also with the depositional model for Clastic Turbidites as described by Mutti et al. (1999). This analogy can be used to infer the facies distribution within the CSF with the predictive facies tract defined for clastic turbidites (Mutti et al., 1999). A tentative facies distribution for a CSF can be anticipated using this approach even without any real control point (well), and keeping in mind some caveats as the different hydrodynamic behavior of clastics and carbonate grains, and the uncertainties on the sediment source of the system under analysis.

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A clear karstified surface has been interpreted on the western side of the 3D seismic survey. This surface is affected by a series of normal faults running NS with the hanging wall block to the East slipped down and the western block affected by the subaerial exposure. The interpreted CSF seems to have been formed along the faults with a NNW-SSE direction toward the foredeep depocenter. The system presents a main feeder channel showing erosive features in seismic, a channel mouth at the slope break and laterally defined by faults and a depositional lobe clearly defined by seismic attribute extractions (RMS amplitude and Swetness).

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Introduction

Carbonate turbidites are much less studied and known of their clastic counterpart. Only recently (Payros and Pujalte, 2008) some attention has been dedicated to the Calciclastic Submarine Fans (CSF hereafter).

Few discoveries have been made in these sediments in the Middle East. In particular, in the Oman Mountain foredeep basin, they represent well known potential reservoir horizons (Hertig et al., 1994). Two discoveries has been made in the the so-called Pabdeh turbidites, namely the Hamidiyah field in Ajman and Bida Salma-1 in Abu Dhabi. Other two wells drilled by ARCO Dubai in the 1990is penetrated Eocene calci-turbidites yielding minor gas and condensates.

Despite this, little attention has been so far dedicated by the Oil industry to these deposits, because of the issues with reservoir quality. Carbonate sediments are much more subject to diagenetic processes than clastic sediments, and this is especially true for resedimented grains. Thus, 3D seismic examples of these possible reservoirs are not available in UAE and, as per author knowledge, in the literature regarding Middle East basins. ADNOC and OMV have recently acquired a 3D seismic survey in the area NW of Al Ain (Granser et al., 2015) covering the southern end of the Pabdeh foredeep. The survey is large enough to image the margin of the foredeep on three sides (West, South and East). This new seismic data provide a good basis for the detailed interpretation within the foredeep basin and consequently, for the needed seismic characterization of CSF.

Methodology

This study aims at defining in detail a CSF through the interpretation of a 3D seismic survey for the first time in UAE. Detailed horizon picking of different seismic cubes (PSTM and RAI) and seismic attribute extractions are the main tools to define geometry, architectural elements and depositional environments of the turbidite system.

Stratigraphy

The Cenozoic (Pabdeh) foredeep of the UAE developed as a result of loading in front of the Omani thrust-and-fold belt verging to the West. Subsidence started during the middle Eocene (Rus Fm.). A thick Eocene and Oligocene succession infilled the basin with shallow marine carbonates at the margins and shales and resedimented carbonates (calciturbidites) at the depocenter. By the end of the Oligocene the basin was closed. Subsequent deposits are represented by alternations of evaporates and continental-derived clastics (the Miocene lower Fars Fm.). The late Miocene tectonic phase partially involved the filling of the foredeep, in the Eastern area of the basin. Unfortunately, the lack of velocity information in the only available well within the 3D survey outline prevented a precise calibration of the interpreted seismic horizon into a semi-regional chronostratigrahic framework. In spite of this limitation, a relative chronostratigraphy and a basin evolution defined by major depositional-structural events can be built with confidence based on the seismic interpretation (figure 1).

A tentative correlation with the outcrop in Jebel Hafeet has been attempted (figure 2), based on the similarities on the stratigraphic evolution between two wells available and located on the western margin of the Cenozoic foredeep and the public available stratigraphic log of the Eocene and Oligocene formation outcropping at Jebel Hafeet (Styles et al., 2006). The sequence is stratigraphically organized in three shallowing upward cycles and the same pattern can be recognized over a distance of about 100kms. In the Author opinion, this evolution records the progressive filling and closing of the Cenozoic foredeep and can be recognized on seismic as well, where the uppermost part of the Asmari formation (Oligocene) is represented by a platform clearly prograding. The progradation is the sedimentary effect of the lack of accommodation space as the filling of the basin progress. The depocenter of the foredeep is not visible in outcrop and has been only partially penetrated in the two wells. It is within the infilling of such a depocenter and within the lowermost, and deepest part of the Eocene succession that calci-turbidites should be expected.

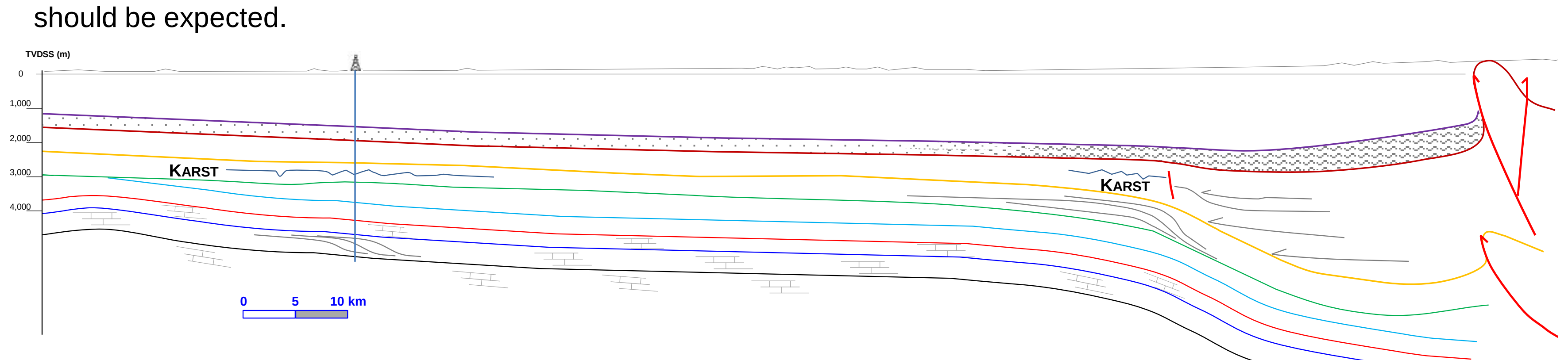
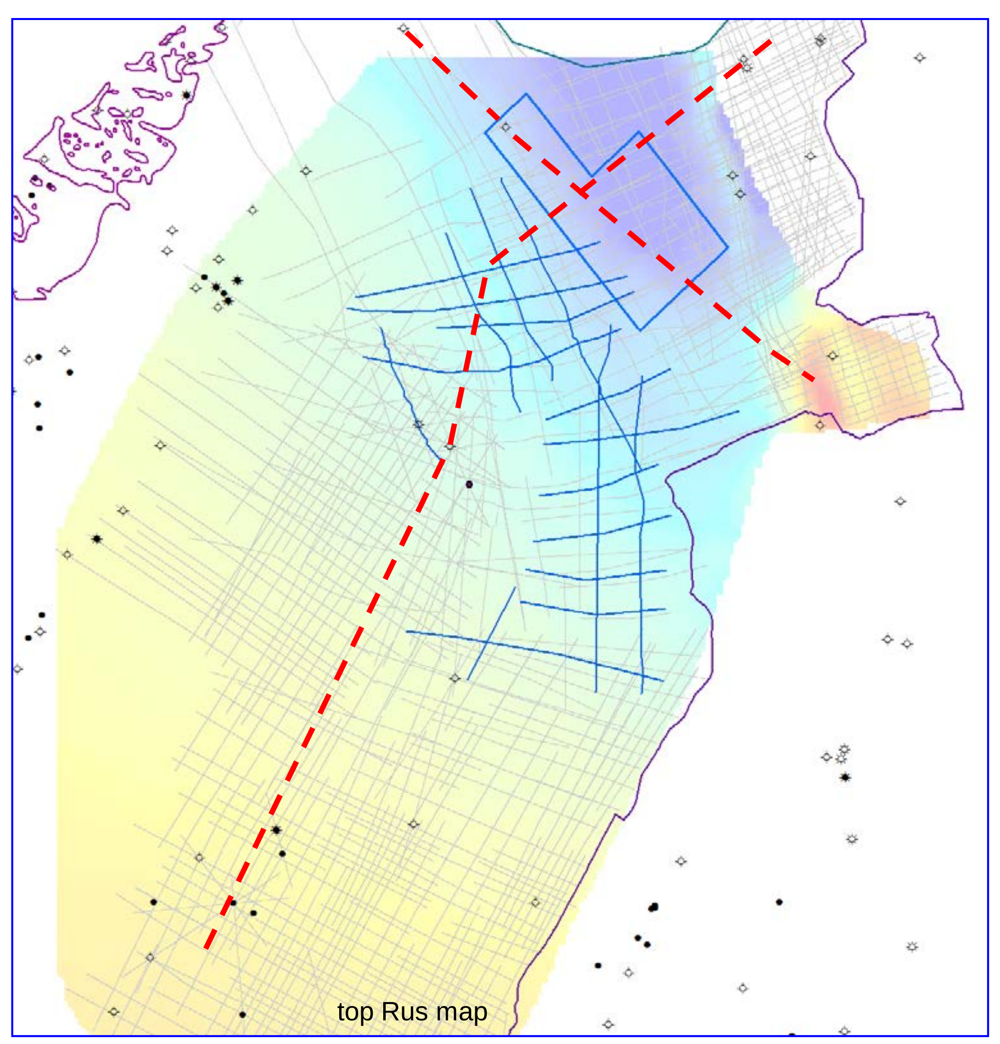
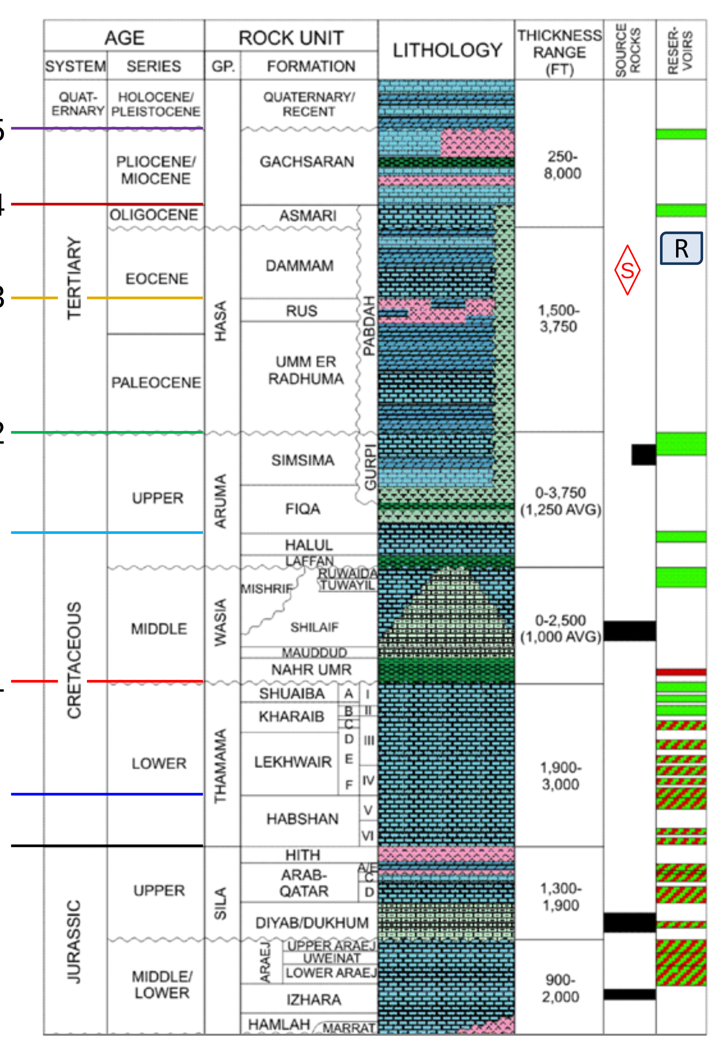
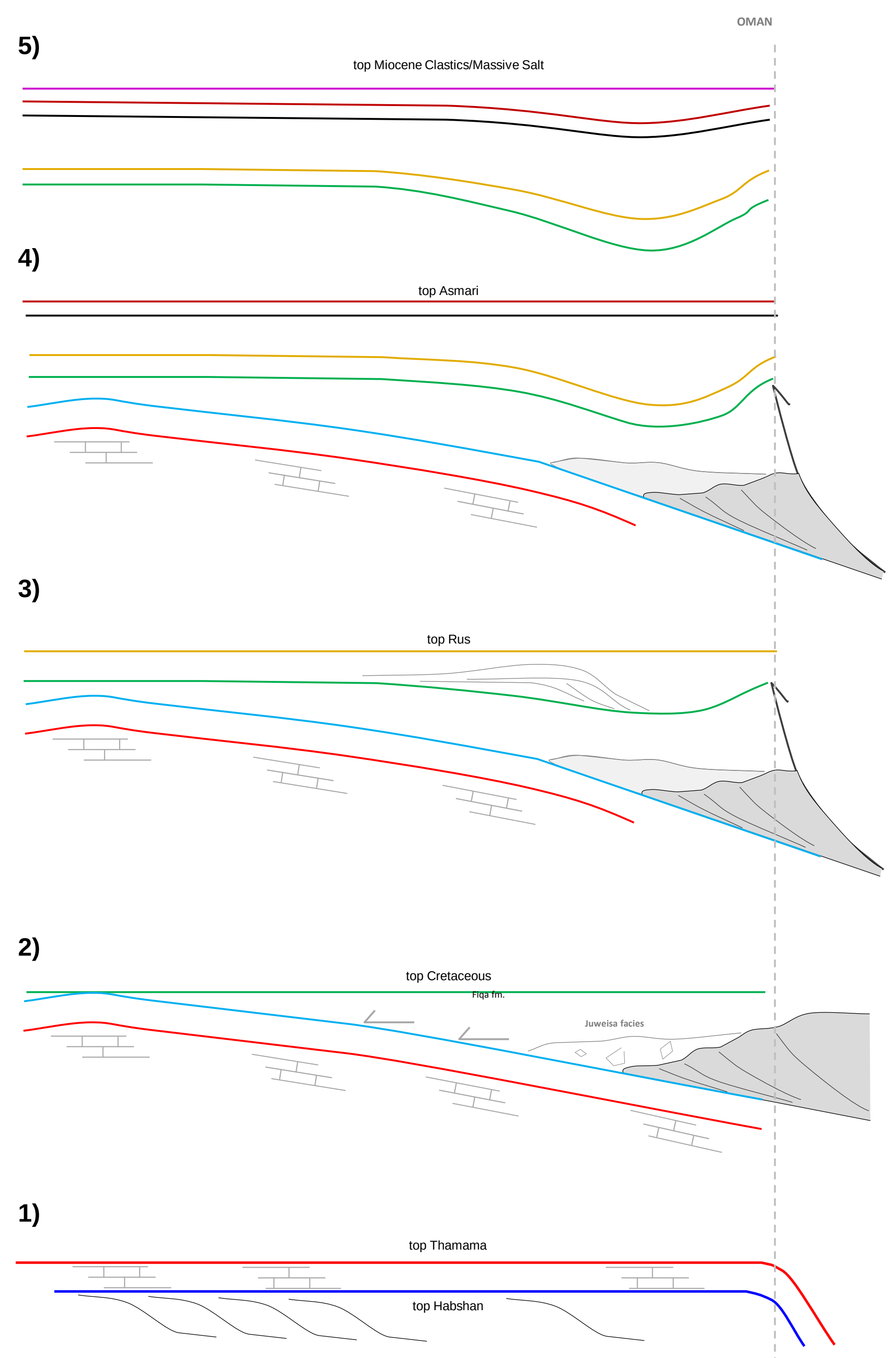


Figure 1







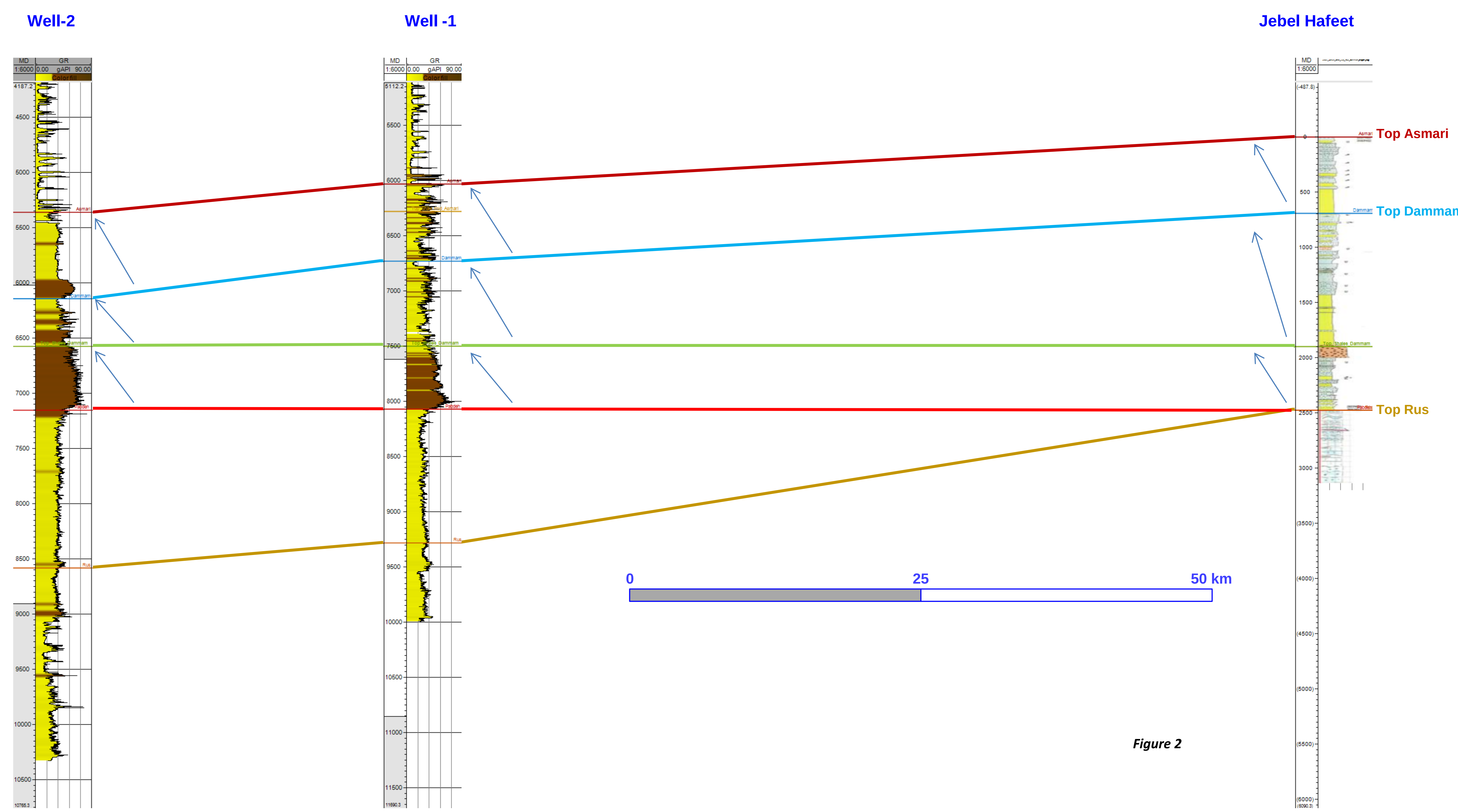


Figure 2

Results

A clear karstified surface has been interpreted on the western side of the 3D seismic survey (figure 3). A clear sink hole is visible on the depth map, but also on seismic sections and in any seismic attribute extraction. This surface is affected by a series of normal faults running NS with the hanging wall block to the East slipped down and the western block affected by the subaerial exposure. Because the nature of these faults, the elevated platform, basin transition is a linear feature clearly visible on the 3D display showing the Spectral Decomposition. The model explaining these fault implies high subsidence near the thrust front and a flexure causing the faulting of the platform toward the foreland bulge. A good modern analogue of the linear feature and his geometry is the white cliff of Dover, even if this geological feature is located in a completely different setting.

The interpreted CSF seems to have been formed along the faults with a NNW-SSE direction toward the foredeep depocenter.

Figure 3

The system presents a main feeder channel showing erosive features in seismic, a channel mouth at the slope break and laterally defined by faults and a depositional lobe clearly defined by seismic attribute extractions (RMS amplitude and Swetness) and visible on seismic cross sections (Figure 4). The erosive character of the channel is clear from seismic interpretation on the Relative Acoustic Impedance (RAI) cube. The depositional lobe appear from the comparison of the RMS Amplitude extraction performed on the base and on the top of the lobe itself. What exactly the high amplitude means in term of depositional facies or porosity is impossible to say due to the lack of any calibration point (well data). Despite this, the geometry of the system can be clearly defined and it shows a coherent and realistic organization in the downward direction.

Figure 4

Discussion

The turbidite system presents a main feeder channel showing erosive features in seismic, a channel mouth at the slope break and laterally defined by faults, and a depositional lobe clearly defined by seismic attribute extractions (RMS amplitude and Swetness).

The mapped SCF shows striking similarities in term of size, environments and architectural elements (Figure 5), not only with the depositional model for a medium-size CSF as depicted by Payros and Pujalte (2008), but also with the depositional model for Clastic Turbidites as described by Mutti et al. (1999). This analogy can be used to infer the facies distribution within the CSF with the predictive facies tract defined for clastic turbidites (Mutti et al., 1999). A turbidite facies tract is the lateral association of genetically related facies that can be observed within an individual bed or a package of strictly time-equivalent beds (Mutti 1992). In other words, it is an ideal model of evolution of depositional facies related to the main flow transformations occurring during downslope motion (Figure 6). The pictures from analogue outcrops shown in the figure are only an examples of possible facies. The characteristics of facies tracts depend mainly on the textural composition of parental flows, amount of bed erosion, flow efficiency (mainly determined by the amount of fine sediments in the flow), and basin configuration. Thus, The Facies Tract of each Turbidite system needs to be defined case-by-case. Depending on those parameters we may have systems with efficient downslope segregation of grain populations and hence depositional facies and also systems not able to separate sediments with different grain size. The result of a poorly-efficient flow are different depositional facies which are generally speaking less "clean". Nevertheless, a tentative facies distribution for a CSF can be predicted using this approach even without any real control point (well), and keeping in mind some caveats as the different hydrodynamic behavior of clastics and carbonate grains, and the uncertainties on the sediment source of the system under analysis.

Depositional Model for the Calciclastic Submarine Fan in the Cenozoic foredeep in East UAE

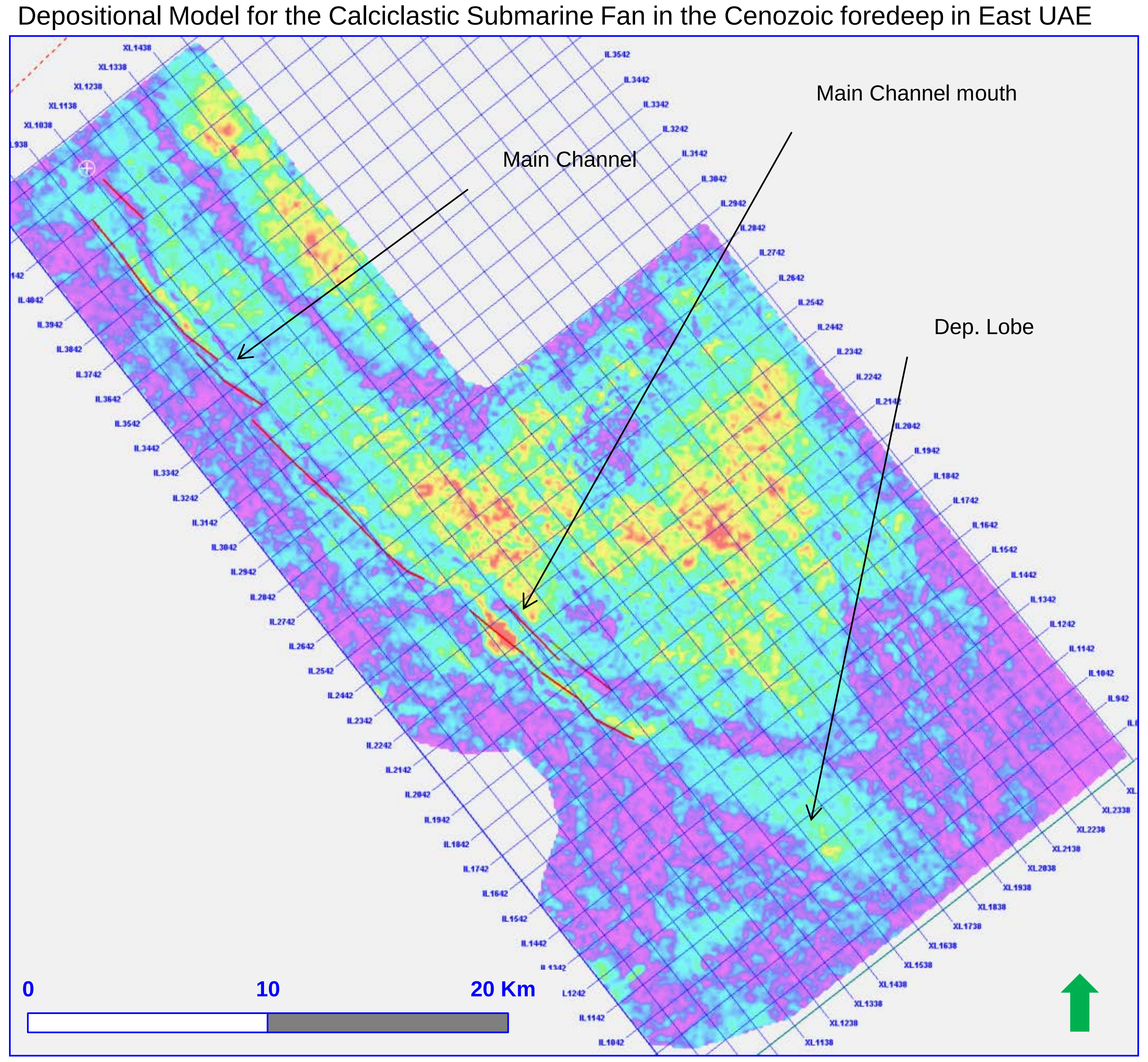
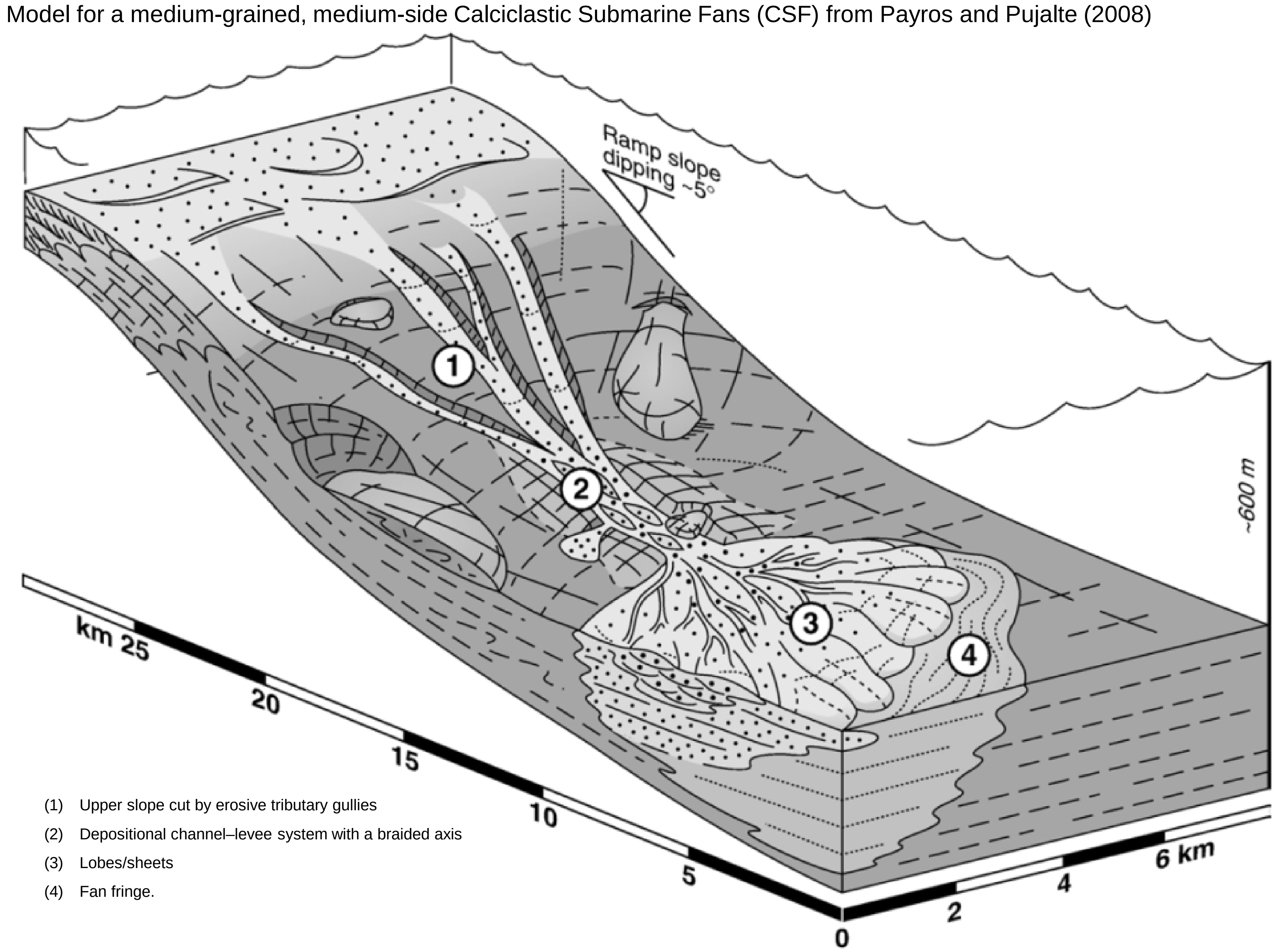
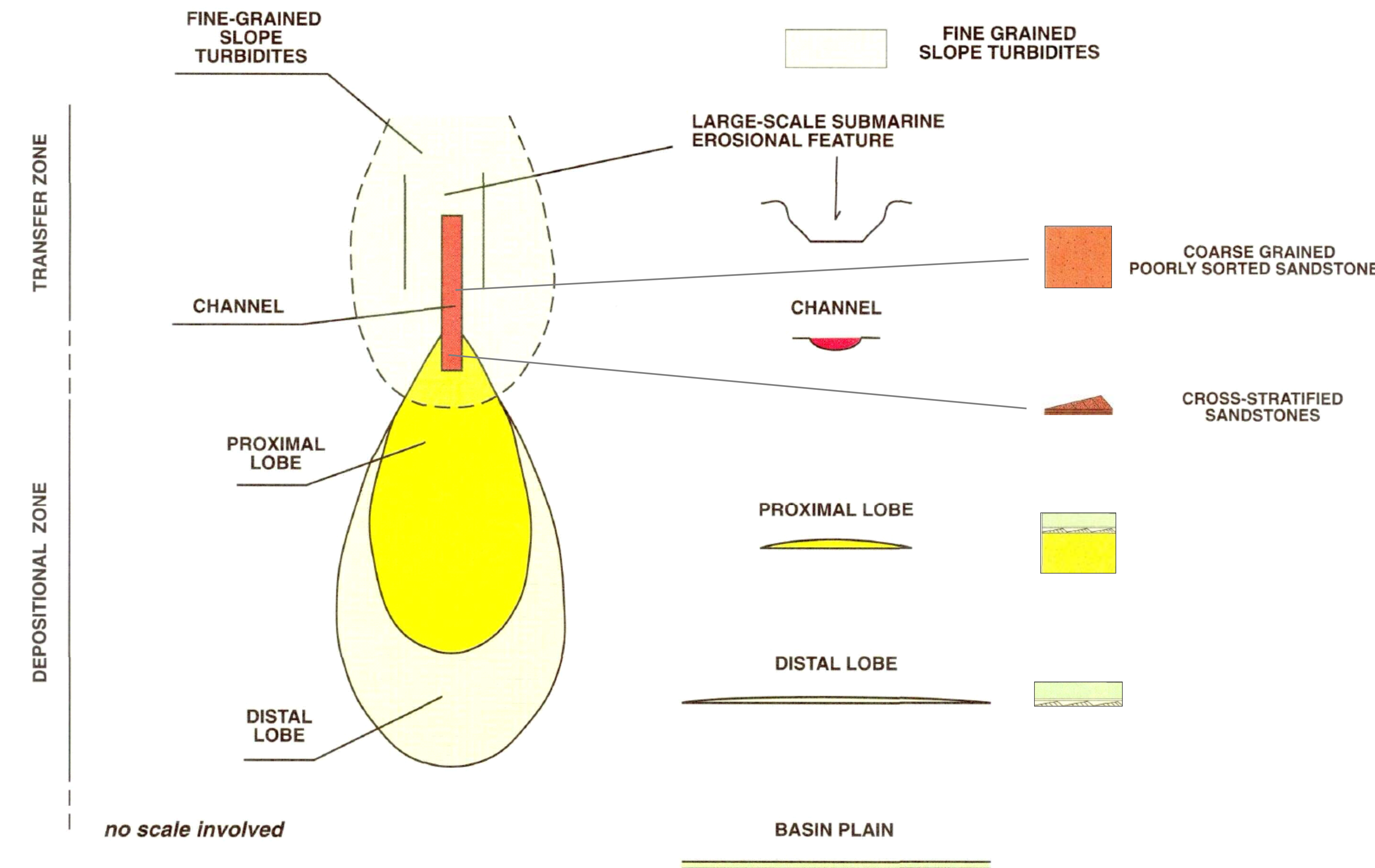


Figure 5

Depositional Model for a medium-grained, medium-side Calciclastic Submarine Fans (CSF) from Payros and Pujalte (2008)



Depositional Model for Clastic Turbidites from Mutti et al., 1999



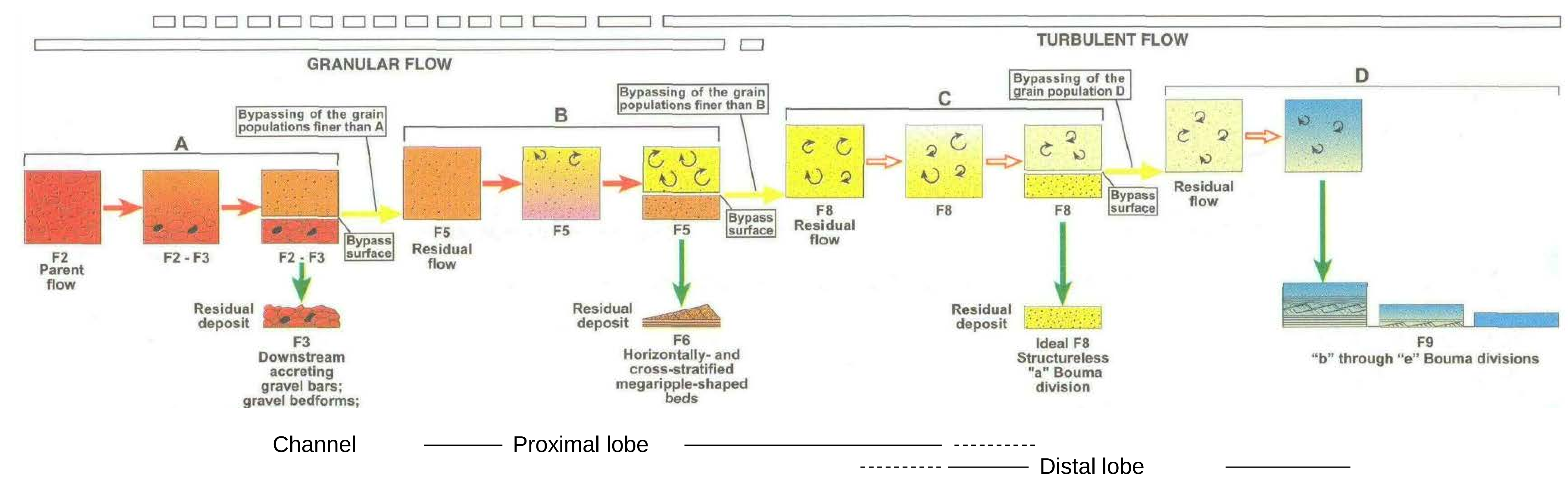
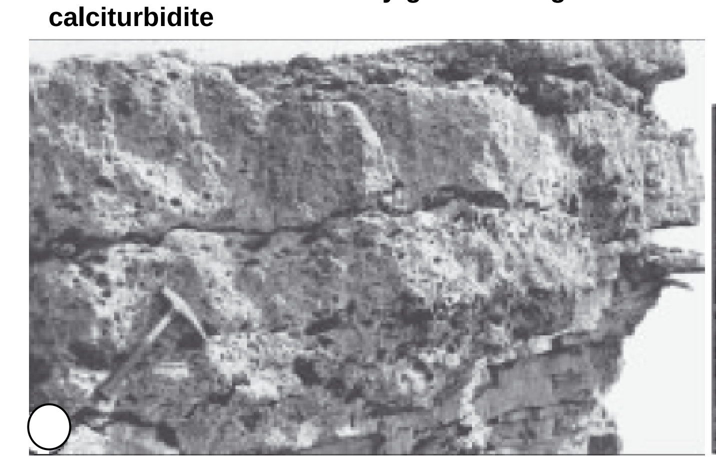


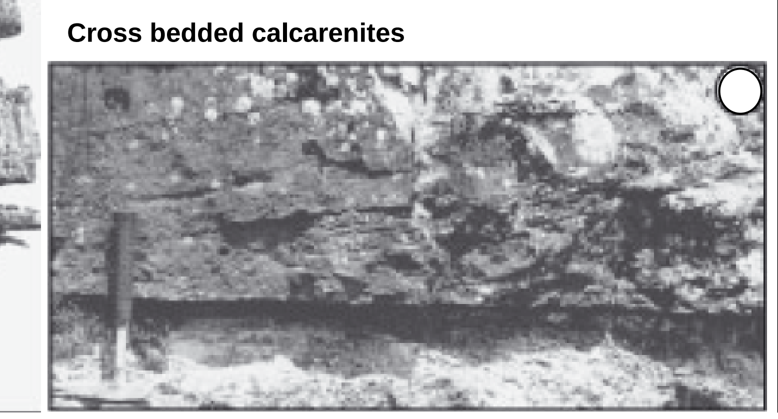
Figure 6

*The pictures from analogue outcrops shown below are only an **examples of possible depositional facies**.*

Erosive based and nornally graded conglomeratic calciturbidite



Cross bedded calcarenites



Massive or parallel laminated calcarenite made mostly of Nummulites (F8 to F9 facies, Mutti et al, 1999)

Conclusions

- For the first time in UAE a Calciclastic Submarine Fans has been interpreted and described through the interpretation of a good quality 3D seismic dataset.
- A CSF has been recognized and mapped in detail within the Eocene infilling of the Cenozoic (Pabdeh) foredeep of the Oman Mountains.
- Calci-turbidites can be a good reservoir, but they need to be understood in terms of facies distribution and architectural elements.
- The mapped SCF shows striking similarities in term of size, environments and architectural elements, not only with the depositional model for a medium-size CSF as depicted by Payros and Pujalte (2008), but also with the depositional model for Clastic Turbidites as described by Mutti et al. (1999).
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