Depositional Environment and Reservoir Facies Prediction of Pliocene, Kafar –El –Sheikh Formation by GDE Mapping technique- A Study from Deepwater part of Nile Delta.

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Keywords

Gross Depositional Environment (GDE), Seismic facies, Deepwater Environment., Seismic interpretation

Summary

The objective of the present study is to predict environment of deposition, sediment dispersal pattern and presence of reservoir facies of the Kafr -el - Sheikh Formation of Pliocene age within the study area located in the deepwater part of Nile delta and eastern Mediterranean basin.
The principal inputs in this study have been the seismic facies maps which describe the large-scale variations and the RMS amplitude maps, excellent tool to identify individual depositional elements such as channel systems, fan-lobes and sheet sands commonly present at deepwater sedimentary environment.
A combination of observational seismic facies mapping and evaluation of RMS amplitudes has allowed a suite of Gross depositional Environment (GDE) maps to be constructed, describing the sedimentological evolution of the study area, and identifying sites of possible reservoir development. GDE mapping shows reservoir potential to be very limited in the Lower Pliocene stratigraphic level. The study area was in too distal a position for sand to be delivered in sufficient quantity or quality. The late Lower Pliocene is the first interval in which viable reservoir appears to have developed; since this time, reservoirs are generally predicted throughout the rest of the Pliocene stratigrpahic succession.

Introduction

The offshore Nile Delta has emerged as a giant gas province with proven recoverable reserves in the region of 42 TCF (Dolson *et al*, 2005); a recent USGS assessment suggests undiscovered technically recoverable reserves in the Nile Delta of around 200 TCF of gas and 1.5 BBO (Kirschbaum *et al*, 2010). In the offshore, gas discoveries have been made as deep as the Upper Oligocene (i.e. The Tineh Field in slope channels,) up to shallow Pliocene discoveries. In offshore setting, the bulk of proven reserves are from the thick Pliocene sediments where sandy slope-channel systems and turbidite fans are sealed within offshore shales. Giant structural and combination traps are formed where these systems cross structural culminations (Dolson *et al*, 2005). The Pliocene sediments of the Nile Delta valley consist of a lower marine sequence of early Pliocene age and an upper fluviatile sequence of the late Pliocene age, and are subdivided into two Formations:1) Kafr El Sheikh formation (Early to Late Pliocene) and 2) El Wastani formation (Late Pliocene).
Majority of the Pliocene reservoirs are restricted within Kafr El Sheikh Formation.Kafr El Sheikh sands are good examples for fining upward turbidities (e.g. Seth, Ha"py gas discoveries). The Study Area is located in the eastern offshore reaches of the Nile Delta area within Eastern Mediterranean Basin (at approximately700-1000m bathymetry) and is primarily located within a diapiric salt basin that is oriented NW-SE(Figure1).This is bounded to the SW by the Eastern and Western Platforms and to the NE by an Inverted Salt Basin .

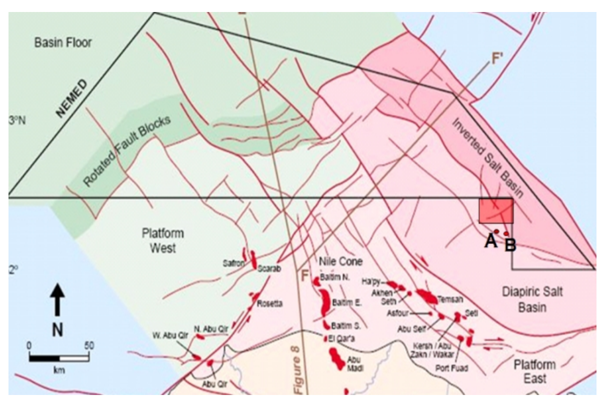

Figure 1: Study area in context of regional structural configuration of offshore part of Nile Delta.

Depositional Environment and Reservoir Facies Prediction by GDE Mapping Technique

Studied area is structurally complex, principally as a result of the plate boundary interactions. . In this region, major early sedimentary tectonic activity occurs in the form of faulting and salt tectonics.

The principle objective of the study is to perform a seismo-stratigraphic and facies interpretation of a 3D seismic volume for the post –salt Pliocene (Kafr-el-Sheikh formation) within the study area. Construct Gross Depositional Environment (GDE) maps to predict reservoir facies occurrence.

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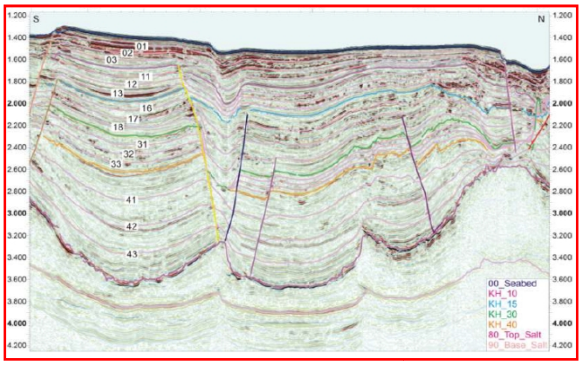

Figure 2: N-S Seismic Section within the study area illustrating the disposition of interpreted horizon.

Methodology

Simple seismic horizon based facies analysis and attribute analysis method have been adopted to construct number of gross depositional environment maps at different stratigraphic level within the broad Pliocene stratgraphic succession of the area under investigation. Detailed workflow can be summarised as follows:

1) Interpretation of structural horizons along with faults to subdivide the stratigrpahic succession.

2) Correlate the structural horizons to the sequence stratigraphically surface based on offset well and available data on public domain.

3) Generate iso-chron map to assess sediment distribution and structural evolution.

3) Assess the distribution of seismic facies within the mapped intervals.

4) Determine the variation of RMS amplitudes variation within these to assess the distribution of lithology changes, and

5) Collation of the last two phase to generate gross depositional environment maps.

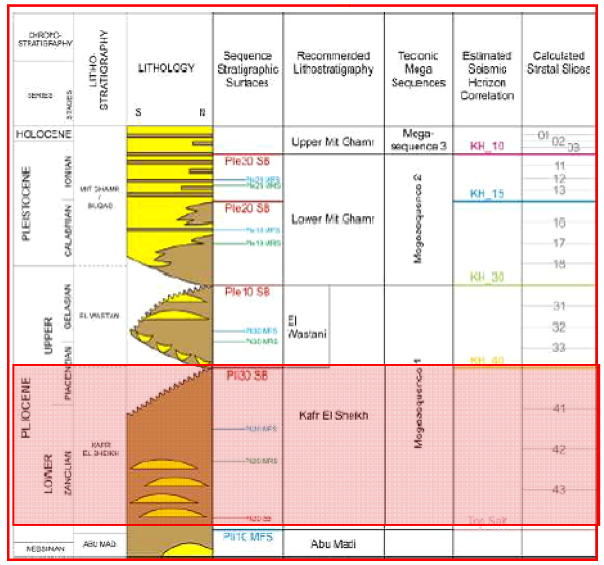

Figure 3: Regional stratigraphy of Nile delta along with correlation of sequence stratigraphic boundaries and seismic horizons

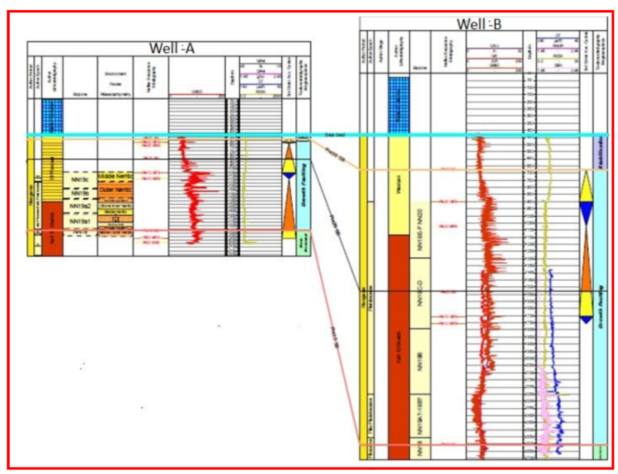

Figure 4: Sequence stratigraphic corelation of offset wells A and B located south of the study area along with biostratigrpahic zonation

Horizon Interpretation

In order to perform detailed depositional environment analysis from the seismic data, the thick post-salt section was divided into more manageable sub-divisions by different structural surfaces that are summarised in Table1. These horizons are picked on the basis that they are strong regionally continuous reflectors that could be picked and tied with some confidence throughout the seismic volume. Wells within the seismic data coverage were not available; hence an attempt has been made to correlate the interpreted horizons with the regionally established sequence stratigraphic marker picked at offset wells (El-Barkooky & Helal (2002).

Horizon	Colour	Peak or Trough	Characteristic	Quality
00_Seabed	Navy	Trough	Very strong reflector everywhere	Excellent
KH_10	Pink	Trough	Prominent unconformity. Generally strong reflector	Very good to Excellent
KH_15	Blue	Peak	Generally strong reflector though can be disrupted	Moderate to Good
KH_30	Green	Peak	Generally strong reflector though can be disrupted	Moderate to Very Good
KH_40	Yellow	Peak	Generally moderate reflector though can be disrupted over significant areas.	Poor to Good
80_Top_Salt	Pink	Trough	Very strong reflector though can be disrupted	Good to Very Good
90_Base_Salt	Pale Pink	Peak	Very strong reflector though can be poor under thick salt diapirs	Moderate to Very Good

Table 1: List of Horizons mapped to subdivide the Post-Salt section.

Correlations between seismic horizons and the prominent sequence boundaries picked in wells are shown in Figure.3 and Figure 5, where in interpreted horizon KH-30, KH-40 and Top of salt is co-relatable with Pliocene sequence boundaries Pli10 SB, Pli 20 SB respectively. The correlation between Ple-10SB and KH_30 is considered to have reasonable confidence as it is a significant regional sequence stratigraphic surface and a major mapable surface in the seismic data which separates higher amplitudes section above from generally lower amplitudes section below.KH_30 horizon is therefore considered to mark the Plio-Pleistocene boundary. It is deemed likely that the most prominent seismic reflector below Ple10 SB (equivalent to KH_30) corresponds to the most significant Pliocene sequence boundary, leading to the proposed correlation between Pli30 SB and KH_40.

Stratal Slice Calculation

Stratal slices are calculated between seismic horizon KH-30 and KH-40 and KH-40 and 80_Top_Salt horizon to divide entire interpreted interval in to several smaller units. Four stratal-slices are calculated to divide each Interpreted interval into four sub-divisions. The isochron of each interval was gridded, divided by four, and the isochron fourth sequentially added to the top-interval horizon.

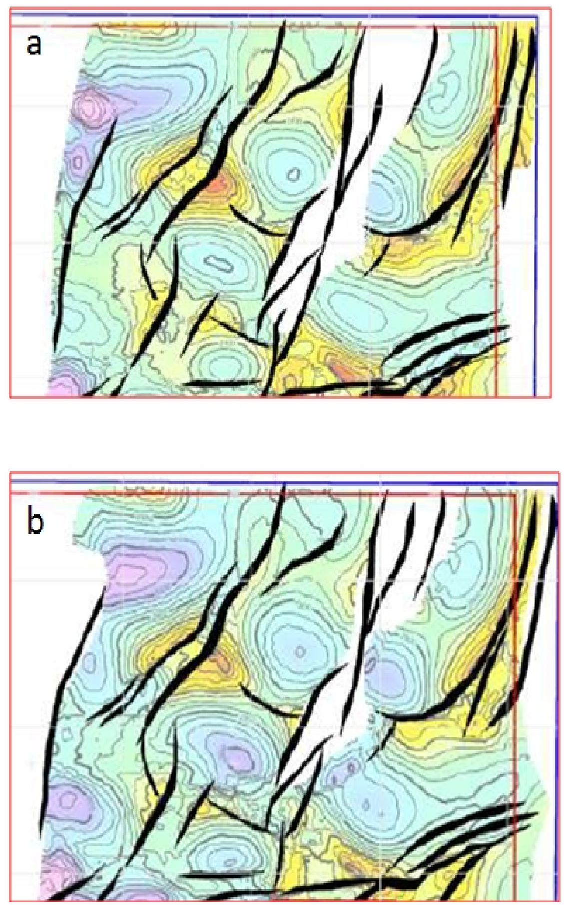

Figure 5: Gridded Horizon a) KH-30 and b) KH-40 in the study area.

Seismic Facies Mapping

Seismic facies maps are constructed through detailed visual inspection of the seismic reflection geometries and character independent of amplitude, rather than an automatic statistical evaluation of the amplitude characteristics. Observation of the seismic data showed that seismic characters in the study area fall into four broad categories (Fig 6):

a) Well banded facie (Bright green colour in the map) representing interbedded shale and silt predicted to be deposited in a quiescent environment.

b) Moderately banded ;(light blue colours on the maps). This seismic character is interpreted as representing shale and silt deposited in a quiescent environment.

c) Disrupted reflectivity (assigned bright blue colours on the maps); represents active environments, with a prevalence of significant high energy depositional systems including turbidity current channels and fan-lobes.

d) Chaotic; character-type - (assigned pink colours on the maps) representing the highest energy environments, dominated by major turbidite systems with their associated channel systems and fan-lobes.

Lower most part of the Pliocene section represented by the stratal facies map between KH-40 to Top of the Salt horizon (Fig 7a) generally consists of well banded facies to moderately banded facies along with mounded opaque facies attributed to Mud mounds/salt pods. Gradational changes of well banded facies to moderately banded facies with lateral disruption have been observed in the upper part of the lower Pliocene stratigrpahic interval. Some coarser clastic input from low energy diluted turbidity flows.

Upper part of the Pliocene section is represented by the stratal facies map between KH-40 to KH-30 horizon (Fig 7b). This interval shows a dramatic change from the underlying interval, with much greater areas defined by moderately banded and disrupted reflectivity facies.

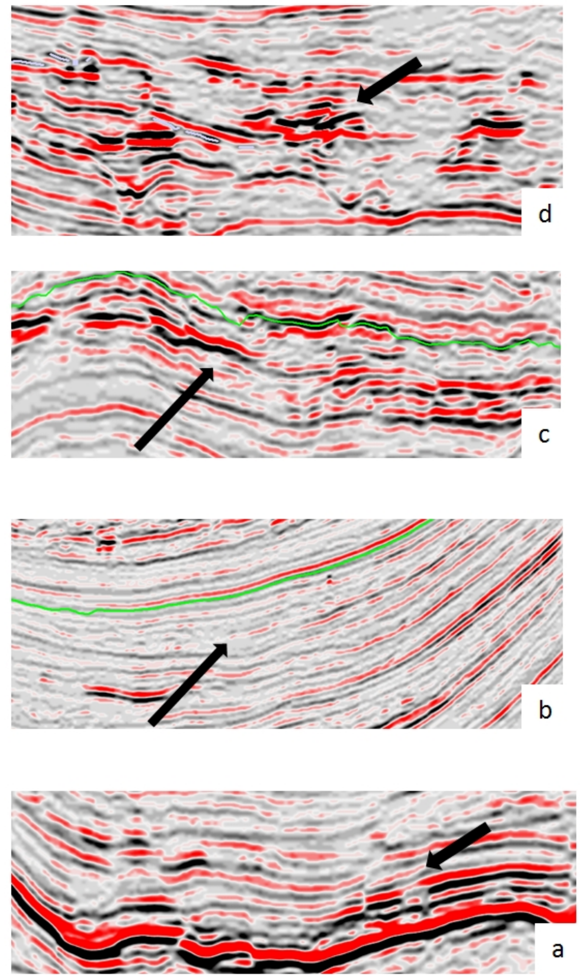

Figure 6: Seismic Reflection character of the identifed facies a)Well Banded b)Moderat Banded c) Disrupted d) Chaotic facies.

Attribute Analysis/ RMS Amplitude Map

Amplitude extractions are an invaluable tool for examining likely depositional features within 3D datasets. RMS amplitude map has been generated corresponding to each interval defined by the stratal slices (Fig 7) . These maps act as major input to the final GDE maps prepared for the each of the stratigraphic interval. Major turbidite channel systems with high amplitudes are very well highlighted by RMS maps. In many cases low amplitude channel type geometries caused by small and ephemeral turbidity flows are observed. Where the amplitudes are higher but do not map out in a coherent pattern, the most likely interpretation is the existence of a complex of small turbidity flow across the zone.

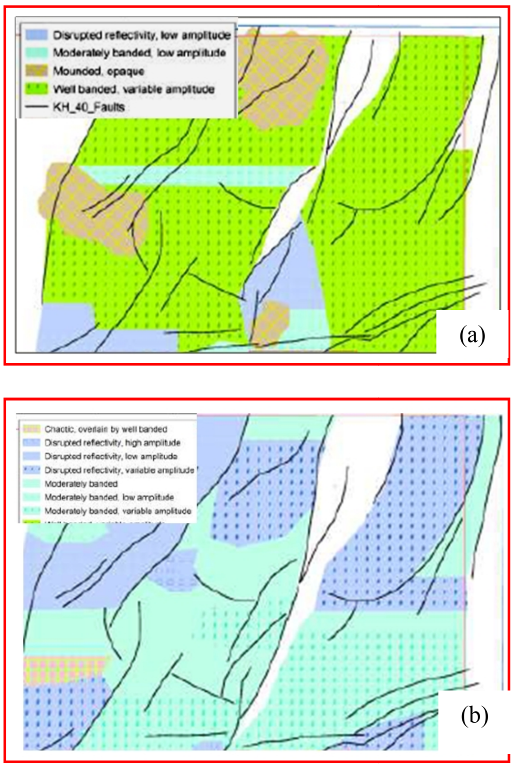

Figure 7: Seismic Facies Map a) KH-30 and KH-40 Horzon b)KH-40 to Top Salt Horizon

Construction of GDE Maps

Gross Depositional Environment (GDE) maps are prepared integrating seismic facies map, RMS amplitude map and isochrones between structural horizons (to account for the sediment flow direction). GDE maps for the lower and upper part of the Pliocene section (Fig 9) within the study are represented in the figure. Interpretation of the map belongs to the lower part of Pliocene section (Top Salt to KH-40) reveals sediments deposition largely out of suspension from the water column, though the influence of dilute low energy turbidity flows is anticipated. Sand rich intervals are predicted in the upper part of the interval where in sheet sands and fan lobes are identified based on RMS amplitude and seismic facies map. GDE map of Upper part of the Pliocene interval (KH-40 to KH-30) indicate more sand development in the form of Major channel system deposited sand, large fan lobe and sheet sands though the background sedimentation was largely mud dominated.

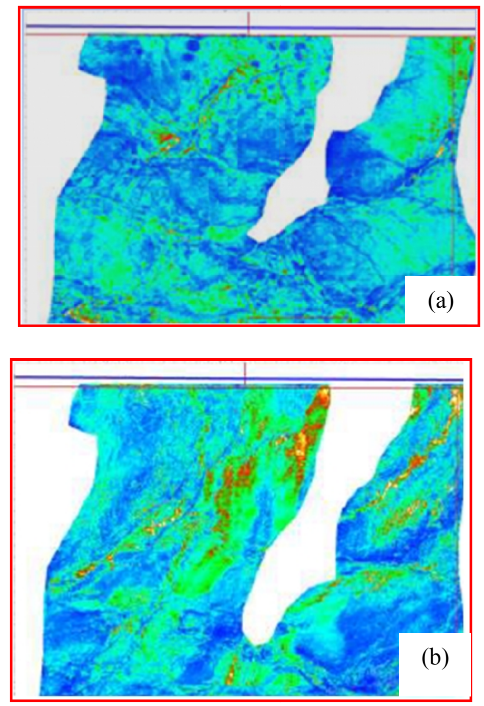

Figure 8: RMS attribute map a) KH-30 to KH-40 Horizon b) KH-40 to Top Salt Horizon

Conclusions

Sequential evaluation of all GDE maps allows major trends in deposition through time to be evaluated. These trends are as follows:

- Depositional environments are cyclical, showing variation between high-energy environments with well-developed major sedimentary systems, and low-energy environments with few small poorly developed sedimentary systems.

(a)

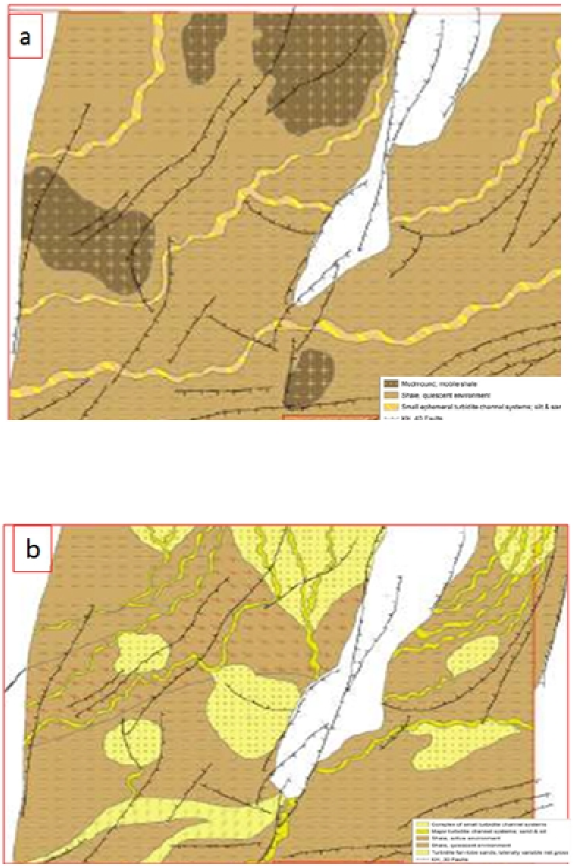

Figure 9: GDE map constructed based on seismic facies map and attribute map a) KH-30 to KH-40 interval b) KH-40 to Top of The Salt interval.

- Within this cyclical setting there is a lower-order progradation through time such that the oldest Pliocene stratigraphic interval represents the deepest water environments.

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- Whilst relative water depths have decreased since the early Pliocene flooding (Pli10 MFS), the study area has always occupied a distal position, (at the present day it would be termed middle slope). It has always been, and still remains, a dominantly mud-prone environment with sand being delivered to the area in confined turbidite channels which then feed lobe-fans and sheet sands.
- There are no widespread ubiquitous sands and reservoir will only be found in the sand-body types described above.
- Reservoirs are likely to be better developed in the intervals that show the highest energy environments.

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