RESERVOIR CHARACTERIZATION AND DEPOSITIONAL PATTERNS OF PLIOCENE AND MIOCENE IN THE NORTH NILE DELTA, MEDITERRANEAN SEA, EGYPT.

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Summary

This study aims to delineate and evaluate the reservoir characteristics and stratigraphic patterns of Miocene and Pliocene sediments in shallow and deep Mediterranean offshore Nile Delta. Pliocene & Miocene reservoirs are ideal cases for shelf slope and sub-sea depositional environment, which deposited as channel fan complex and deep seated sub sea channels.

Pliocene reservoirs are represented by Kafr El Sheikh and El Wastani Formations. Kafr El Sheikh sands are good examples for fining upward turbidities sequence in the down thrown side of east-west growth faults (e.g.. Seth, Ha"py, King & Max gas discoveries). Kafr El Sheikh formation is considered the primary reservoir for many recent gas discoveries with very thick net pay.

On the other hand, Abu Madi Formation (Late Miocene) in which it has a very high reservoir potentiality is represented by flluivo-marine meandering channels or paleo-valley. (E.g. Baltim gas field). Wakar & Sidi Salem sands (Oligocene) have been deposited in sub sea channels and fan complexs (e.g. Wakar, Temsah gas fields) respectively.

By using the most updated petrophysical techniques (Elan, ECS, CMR & Tri-Axial Resistivity/3D method) help to define the fine-grained thin laminated reservoirs, differentiate the different facies, depositional models and the stratigraphic pattern.

These reservoirs of the tertiary section are widely distributed westwards, northwards and eastwards in the whole Mediterranean basins, which encourage the gas exploration.

Discussion and explanation

Structure setting and stratigraphy:

The hinge zone which is a set of the E-W normal faults with a big throw down to the north, controlling the origin of the Nile Delta. A large thickness of Tertiary section is deposited north of the hinge zone in different environments changes from high stand to low stand including nerritic, bathyal and abyssal zones. The other two tectonic elements that affect the Nile Delta setting are the Bardawil and Rosetta trends. Far from the Nile Delta cone, eastward and westward, the tertiary thickness is reduced, and the Mesozoic gets shallower.

North Nile Delta and Mediterranean Sea (Tertiary basins) are characterized by a big gas province, including many big and small gas fields distributed onshore and offshore, shallow, deep and ultra deep, with water depth up to 3000 m.
Those gas fields are producing from Pliocene and Miocene sands, which have thicknesses ranges from few meters to150 m.

Continental Shelf depositional environment.
It is represented by meandering, fluvial channels, point bar and levees environments. (Miocene-messinian) Abu Madi sand channels, like Abu Madi, Wastani, Nidoco and Baltim gas fields.

Shelf slope depositional environment.
That environment, prograding delta is represented by slope fans, slope channels, sand lobes and mouth bar sands (Miocene-Serravallian) Sidi Salim and Serravallian sand lobe I, II & III in Temsah gas field, Scrab gas discovery, Abu Madi sand in King gas/oil field.

Basin floor fan depositional environment.
Is represented by basin floor fan and deep seated channels which are deposited as thick turbidit sequences e.g. Kafr el Sheikh sands in Seith, Haapy, Abu Sir, King gas fields.

Those deep water sands are the primary reservoirs in the Mediterranean Sea due to high porosity and high permeability and its large thickness reaches to 150 m.

paleonotogical studies support these environmental zonation or environmental patterns.

Seismo-stratigraphy .
The tertiary section in the Nile Delta and Mediterranean Sea can be classified into two main seismic sequences representing two main sedimentological cycles.

Pliocene seismic sequence, which is characterized by parallel, near horizontal seismic reflectors, changes laterally to bright spots indicating gas-bearing sands as the form of fans or sand channels (Kafr El Sheikh), e.g. (Seth, Haapy).

Miocene seismic sequence which is classified into two subsequence deposited due to unconformity

a- Messinian subsequence (Abu Madi, Qawism)

Messinian subsequence is characterized by lobes reflection patterns or channel fills (lense shape) parallel to the strike direction (Abu Madi and Qawasim Fms) as Abu Madi, Baltim fields.

b- Pre Messinian (Serravalian) subsequence (Sidi Salem Fm).

Pre-Messinian subsequence (Serravalian) is characterized by Sidi Salim fm. sequence which has truncation surface at the base of Messinian in the southern area of delta onshore as Abu Madi and Wastini fields, while to the north, the formation is changed to parallel unconformity overlying folded sand

Paleontological studies confirm the depositional model for these formations as Agip concession (Temsah field).

Each reservoir will be discussed below to describe the depositional environment, seismo-stratigraphy and petrophysical characteristics with some examples

<u>Methodology</u>
Last studies and publication of AAPG (Memoir 26&57) of seismostratigraphy, reference manuals of sedimentology e.g. Celly 1965, showed that the depositional environment has a great significance of the seismic reflection patterns, seismic

configuration and the external form. besides the E.logs response, paleontological studies and paleo bathymetry.

Pliocene reservoirs

A-Kafr El Sheikh Formation

Age: Lower- Middle Pliocene

Lithology: mainly shale, with little carbonate with sand intervals ranges in thickness from a few meters to over 200 m.

Seismostratigraphic features: near to horizontal northward gentle dipping) indicating to basin floor environment, sometimes have fan or sheet form reflectors indicating submarine basin floor fan. Time slice map shows channel fan form Listric growth faults are dominated in Kafr El Sheikh sequence.

Example: Seth, Haapy, King, Abu Sir, Scrab & Semian gas fields

Petrophysics: it is the primary target in Mediterranean Sea and Nile delta. Where in Seth gas field, porosity ranges between (26-31), SW ranges between (16-25) and net pay about 100m.

While, in Abu Sir gas discovery, its average porosity about 29, Sw about 24%, net pay 120 m and average permeability greater than 500 md.

Log response: Gamma ray, sonic (fining upward) or (graded bedding), and a very thin laminated clastics resolved only 3D explorer and FMI logs.

Depositional environment: turbidite fan sequence in basin floor environment, e.g. Seth and Haapy gas fields. Also as slope channels in Scrab gas discovery. The base of Kafr el Sheikh formation is characterized by the presence of *Sphaeroidinellopsis* as indication for marine transgression, or prograding delta fans on downthrown side of growth faults e.g. Darfeel gas anomalies.

Miocene reservoirs

A-Abu Madi formation

Age: messinian

Lithology: shale with sand interval with different thickness occasionally slightly calcareous

Seismostratigraphic feature: lenses shape (channel fill) meandering

Sigmoid in case of shelf fluvial environment time slice maps show meandering channel e.g. Baltim gas field, Abu Madi gas field (clinoform) shape in case of prograding delta, or delta fan in case of shelf slope environment e.g. Abu Qir gas field.

Example: Abu Madi gas field, fluvial channel and delta plain. Baltim gas field channel fill or paleo-valley & El King, Abu Qir prograding clinoform of Abu Madi formation.

Petrophysics: in Abu Madi and Baltim gas fields, the average porosity 22%, average Sw about 30% and net pay about 31 m. core analysis shows the Kv about 120 md, and Kh 150 md in Abu Madi formation for Abu Madi gas field.

Log response: elongated channel fill (Baltim channel) coarsing upward in case of prograding delta /delta plain e.g. Abu Qir, Nidoco.

Depositional environment:

Fluvio marine environment on shelf / shelf slope (delta plain/ delta front), which is indicated by brackish water Benthonic forams, in situ marine *Dinoflagellate.*

B-Qawasim formation

Age: Early Messinian

Lithology : shale with very coarse to medium sand and conglomerate interlayer.

Seismostratigraphic features: Channel fill with flat to top, with high amplitude reflector showing clastic sand shale intercalations, or layering, terminated laterally at bottom unconformity surface. Bounding base messinian and top of Sidi Salem formation truncation.

Example: onshore delta e.g. Abu Madi gas field and Tel Ahmar and Sidi Ghazi locations.

Petrophysics: porosity in Abu Madi gas field averaged 17% and gross sand thickness about 70 m.

Log response: serrated elongated fining upward.

Depositional environment: on shelf alluvial environment.

C-Sidi Salem formation

Age: Tortonian- Serravalian

Lithology: shale with sandstone bodies or lobes coarse to fine grains.

Seismostratigraphic features: The seismic sequence of Sidi Salem is bounded by top Tortonian or base Messinian unconformity or truncation surface, bound dip reflectors downlaped at the bottom surface of the sequence offshore Nile Delta. These dip reflectors are parallel to depositional surface or bottom sequence which is considered as shelf slope environment.

Examples: Temsah Serravalian sand lobes and submarine fan.

Petrophysics : the net pay about 16 m, average porosity 22%, average SW up to 47%. Thin layers are not included in the pay count.

Log response: gamma ray & resistivity logs behave the serrated fining upward, indicating for the thin Serravalian lobes.

Depositional environment: Shelf slope channels or lobe complex, or prograding delta.

Conclusions:

1- Pliocene turbidities deposited as basin floor fan is considered the best reservoir quality due to its net pay thickness, permeability and porosity.

2- Drilling in ultra deep-water depth (greater than 2000 m) have low risk, where thick Pliocene and Miocene sands have big bright spot anomalies. It have deposited as delta fans and basin floor fan.

3- Eastward and westward in the Mediterranean Sea, there are two provinces of gas and oil in Tertiary and Mesozoic sections in case of shallow depth.

4- Turbidities thin laminated clastic is a good addition for gas production and well resolved with new technology logging tool e.g. 3D or triaxial resistivity, FMI and CMR.