The Significance of the Tectonic Evolution on the In Situ Stresses in Rift Basins, Gulf of Suez

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Outlines

- Objectives
- Overview on the Gulf of Suez
- In situ Stresses definitions
- Gulf of Suez tectonic evolution
- Sedimentary pattern in GOS affected by tectonic evolution
- Vertical stress variation
- Pore pressure variation
- Horizontal stresses variation
- Case study on Morgan and Younes fields

Objectives

- Understanding the relation between the tectonic evolution of the Gulf of Suez and the in situ stresses
- Studying the effect of the field basinal location on the stratigraphic pattern and the overburden pressure
- Enable the well planner to anticipate the location of possible abnormal pressure zones in GOS
- Minimizing the drilling cost by estimating the appropriate pore pressure and the fracture gradient which help in avoiding well controls incidents and mud losses
- Avoid the environmental pollution and loss of human life injuries resulted from abnormal pressure problems
- Studying the stresses magnitudes in the field with representing the appropriate analogue in any further work
- Ideal workflow for any further wellbore stability starting from Basin modeling and selection of the optimum analogue data based on the basin location

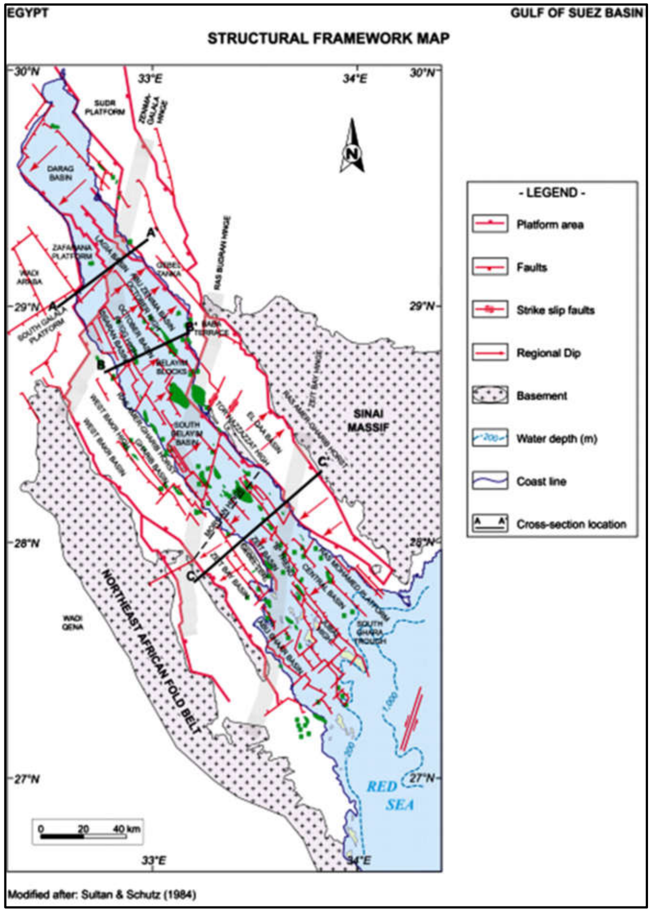
Overview on Gulf of Suez

The Gulf of Suez is an intercontinental rift separating the Sinai Peninsula from the northern Eastern Desert. It extends for about 325 km in a north–northeast direction from Hurghada in the south to Suez City in the north.

This area is characterized by highly faulted structural Blocks Started in evolution at the beginning of the Miocene times. Source rocks and sandy reservoirs are abundant in both the Pre-rift and the post-rift sedimentary rocks
(Shahin and Shehab, 1984).

Most accumulations of crude oils in the Gulf of Suez are found in different reservoirs and pay zones, ranging in age from Paleozoic to Middle Miocene.

These accumulations mostly occurred in structural fault blocks formed at the time of rifting (Chowdhary and Taha, 1987).



Structural framework map for the Gulf of Suez modified after Sultan & Schutz (1984)

In Situ Stresses definitions

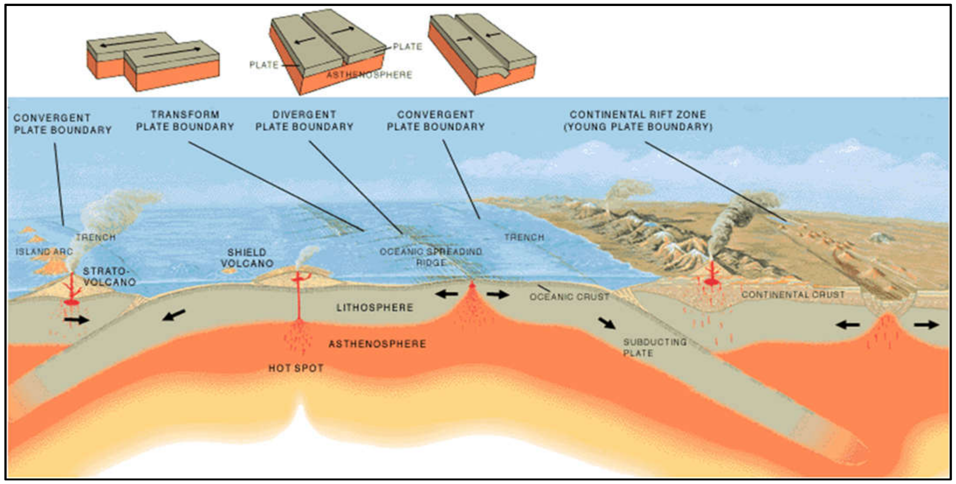
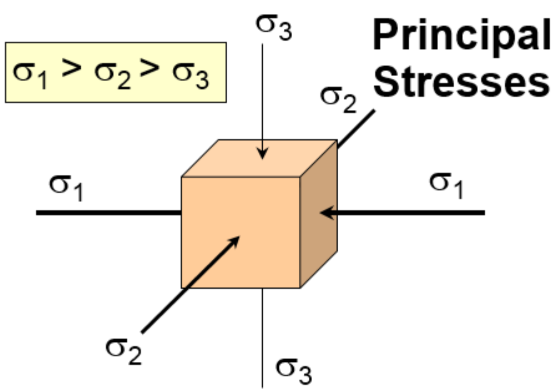
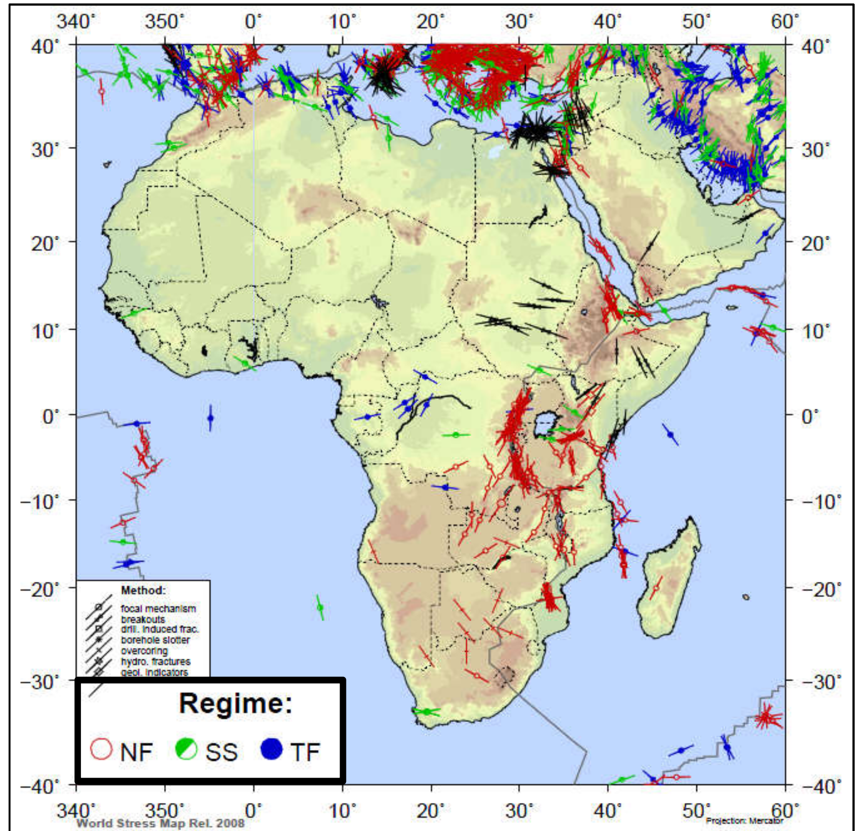


Plate tectonics is one of the main reasons resulting in stress yielding, which is concentrated in the plates boundaries



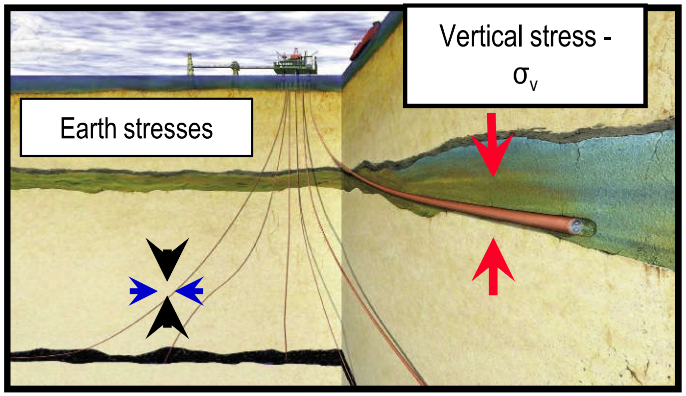


Africa stress map

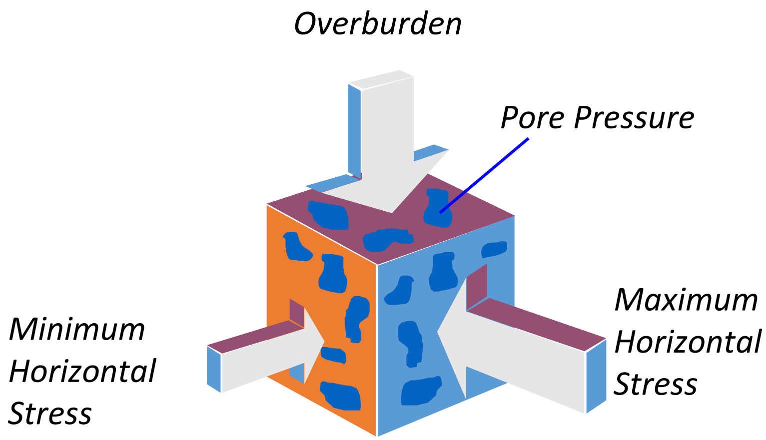
Different types of faults in Africa indicate the Stress distribution and orientation

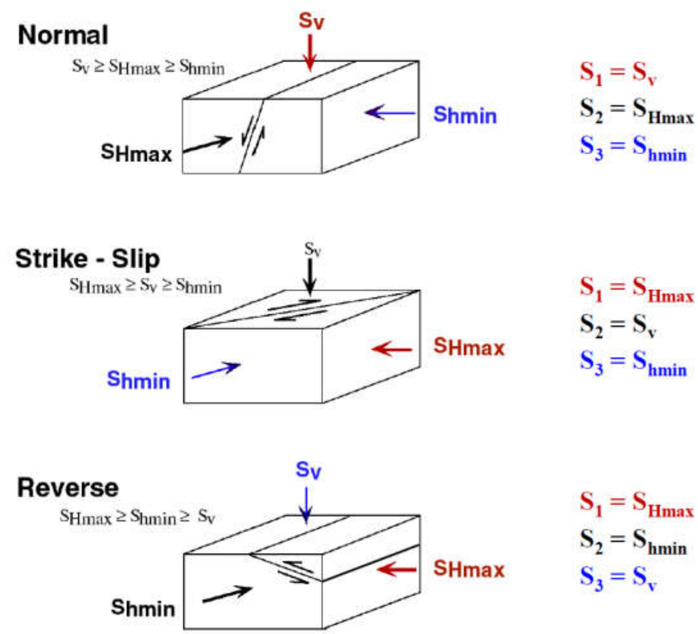
World Stress Map Rel. 2008. Heidelberg Academy of Sciences and Humanities
Geophysical Institute, University of Karlsruhe

In Situ Stresses definitions



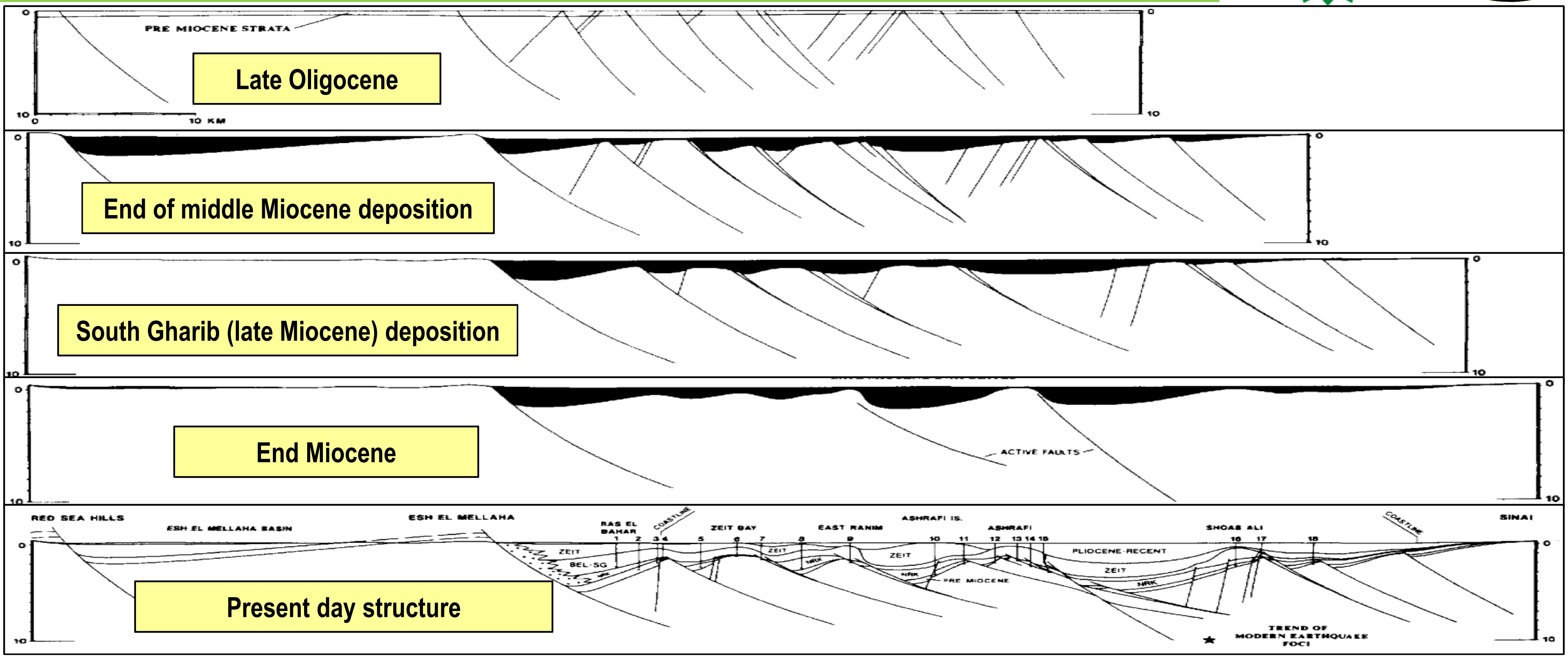
Effect of the stresses on the wellbore hole





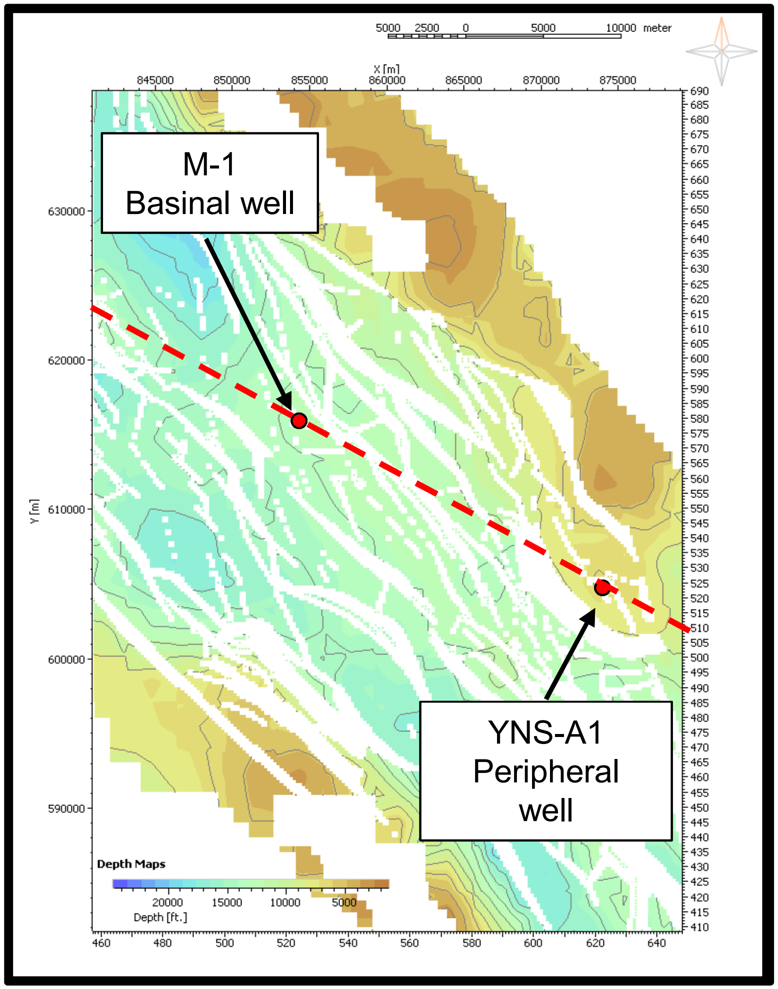
Anderson classification of relative stress magnitudes

Gulf of Suez Tectonic Evolution



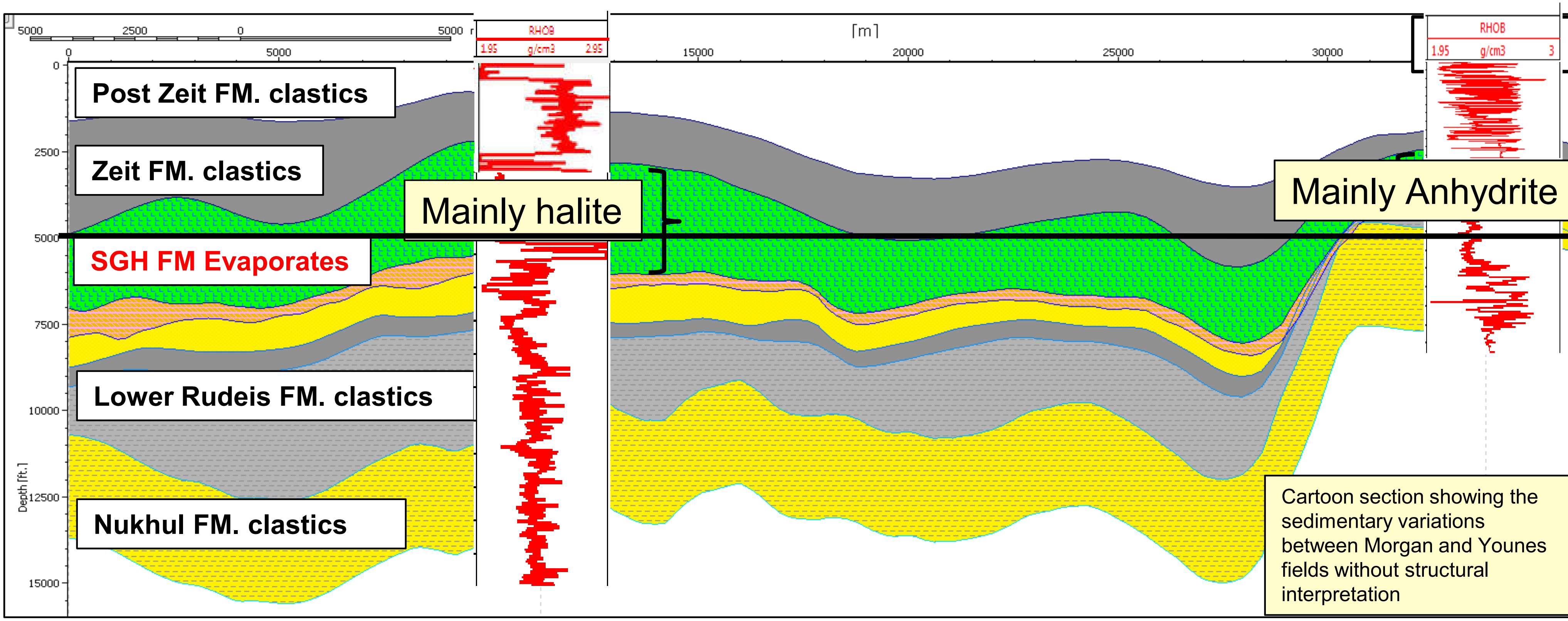
Spatial and temporal evolution of sub-basins in Southern gulf of Suez, Black shading represents sediment accumulated during each indicated time interval. **After BOSWORTH 1995**

Sedimentary pattern in GOS affected by tectonic evolution



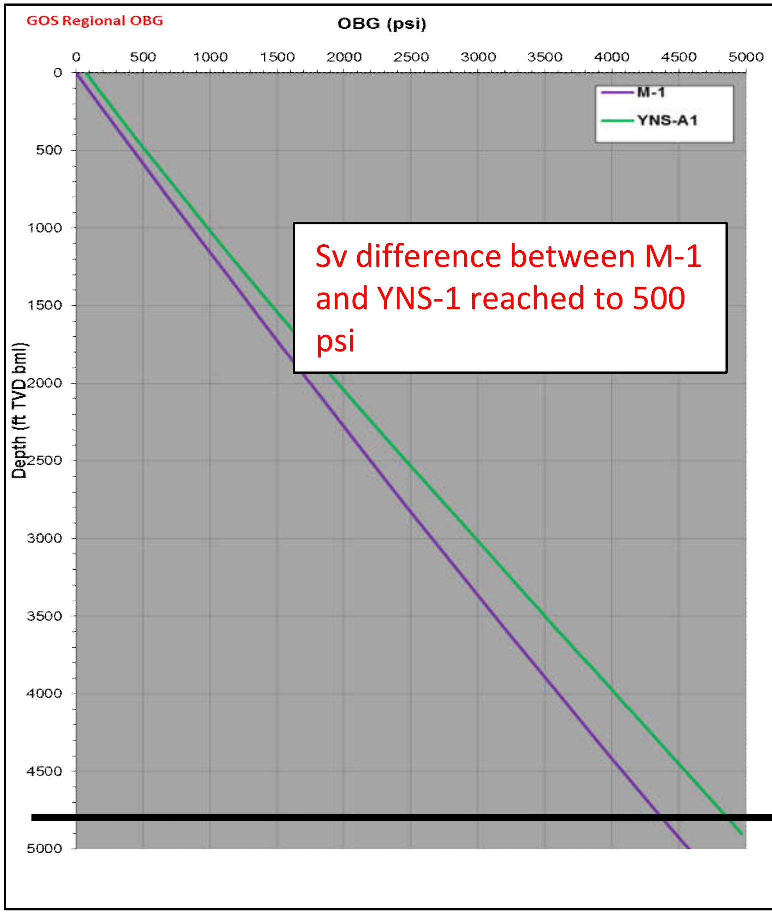
- 2 ideal wells from different locations in the basin: 1 peripheral (Younes well) and the other is basinal (Morgan well) have been selected to show the sedimentary pattern variation between the 2 locations affected by the tectonic evolution of the Gulf of Suez
- 2 locations were well studied as initial point in the new wellbore stability studies to be applied in the new prognosis wells to avoid the previous wells problems
- A cross section between the 2 wells is selected to show the lithological and thickness variations

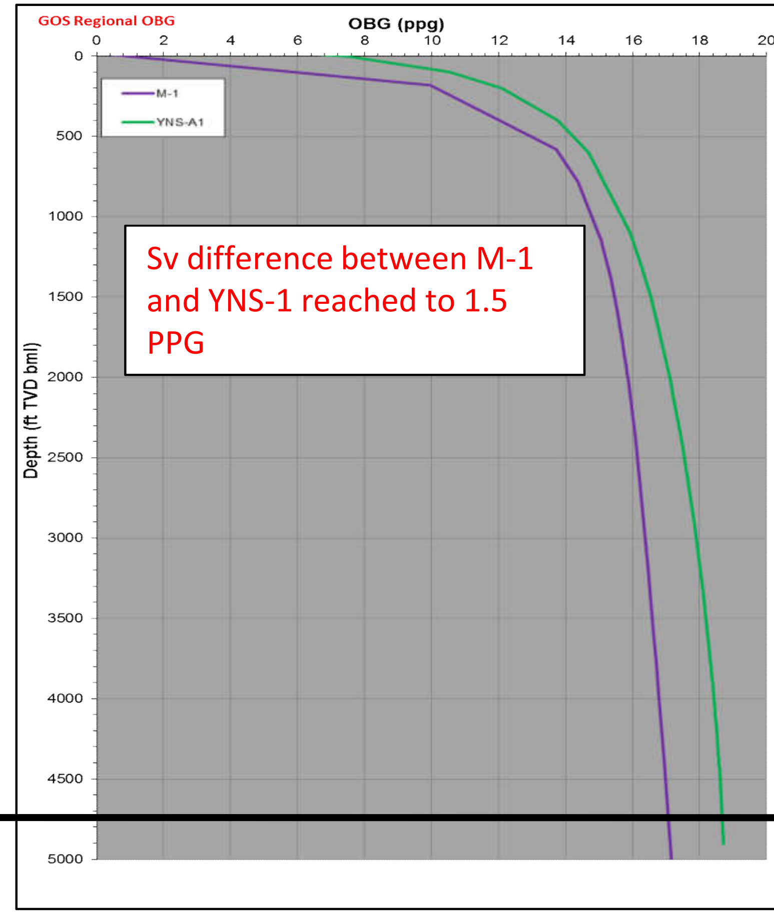
Sedimentary pattern in GOS affected by tectonic evolution



The change in the sedimentary pattern between the peripheral and the basinal wells is clear in the Miocene section (especially South Gharib formation) thickness and lithology. M-1 well with thick section (more halite section due to the continues water supply from the sea in the basin despite of the restriction conditions). YNS-A1 well thin section (more anhydrite content due to the high restricted conditions rich in sulfates).

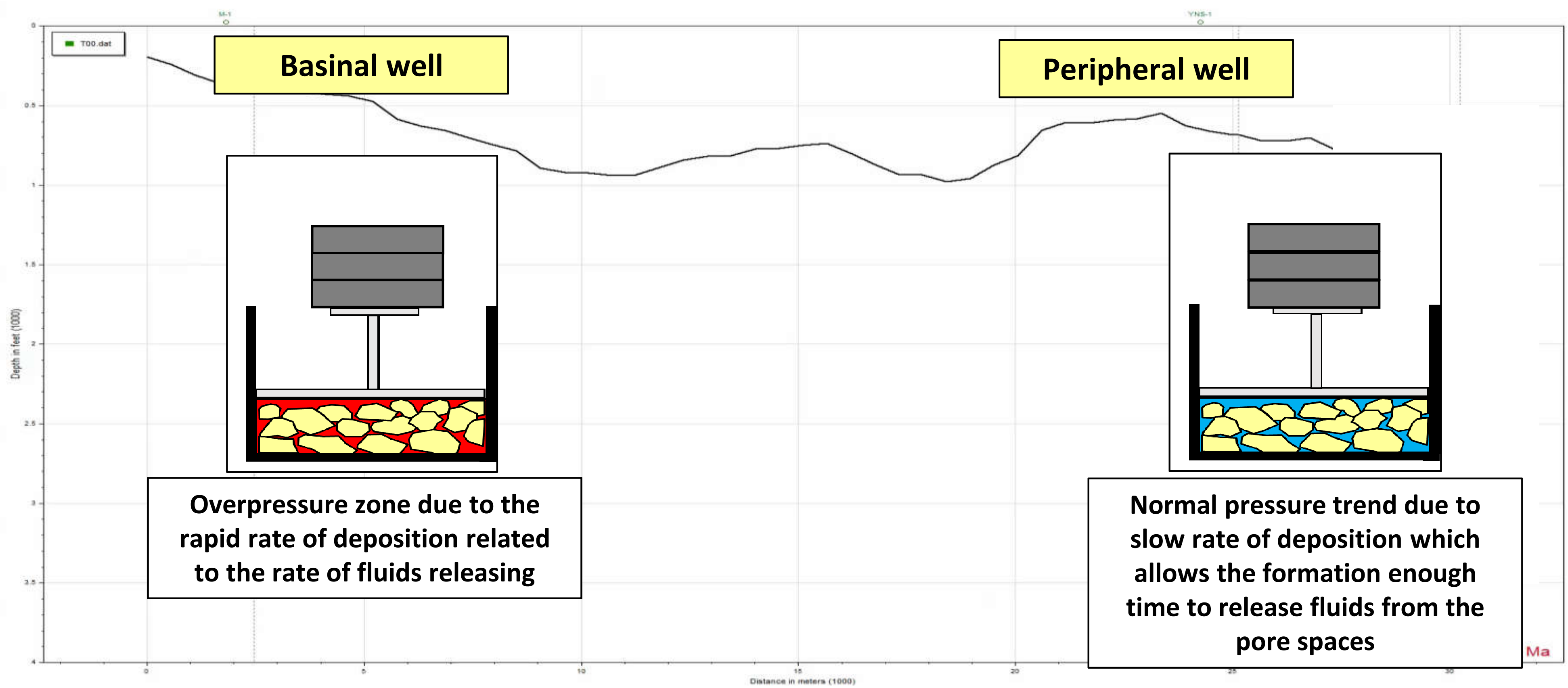
Vertical Stress (Overburden Pressure) Variation





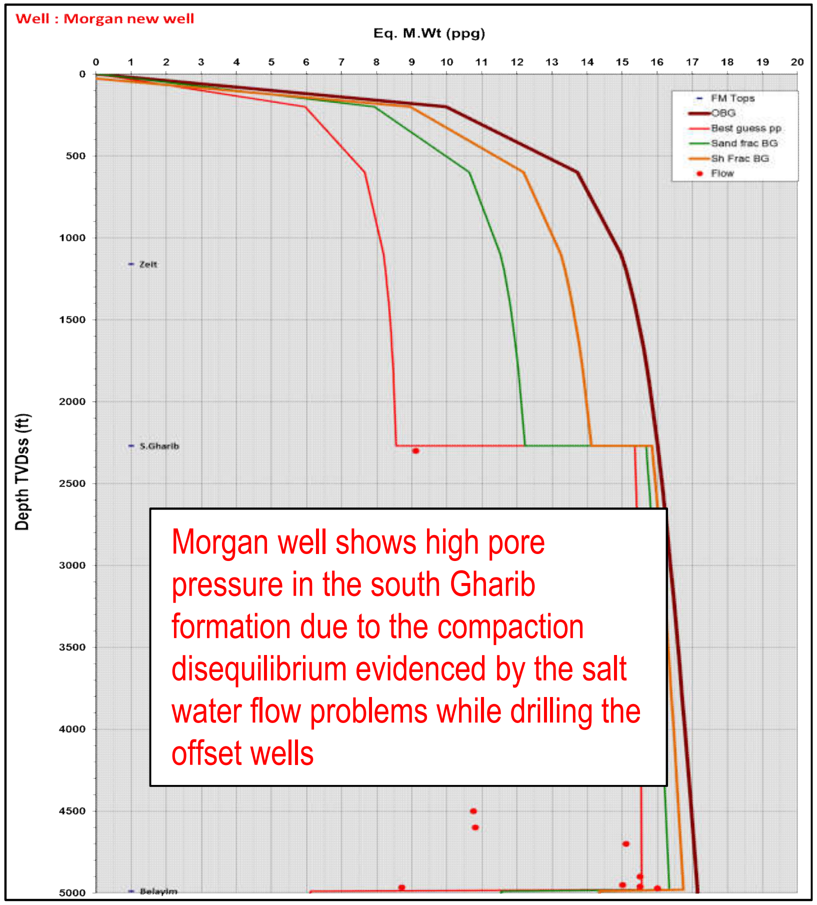
The change in the sedimentary pattern between the peripheral and the basinal wells had a direct impact on the overburden gradient

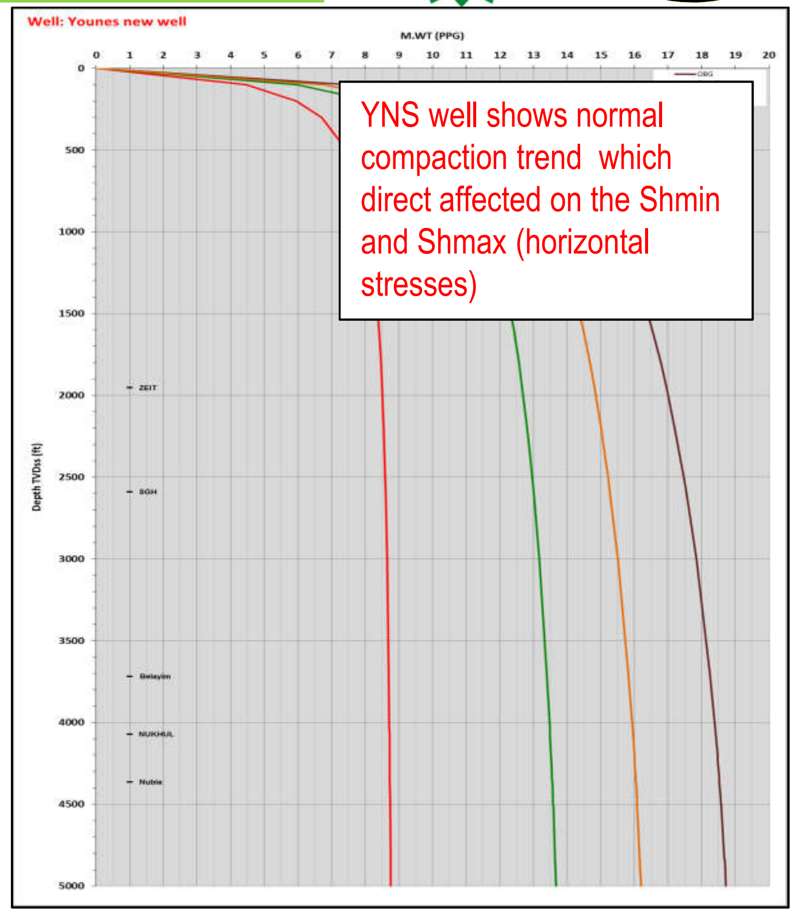
Pore Pressure and Horizontal stresses variation



2D burial history showed rapid rate of deposition resulted in overpressure zones due to the compaction disequilibrium

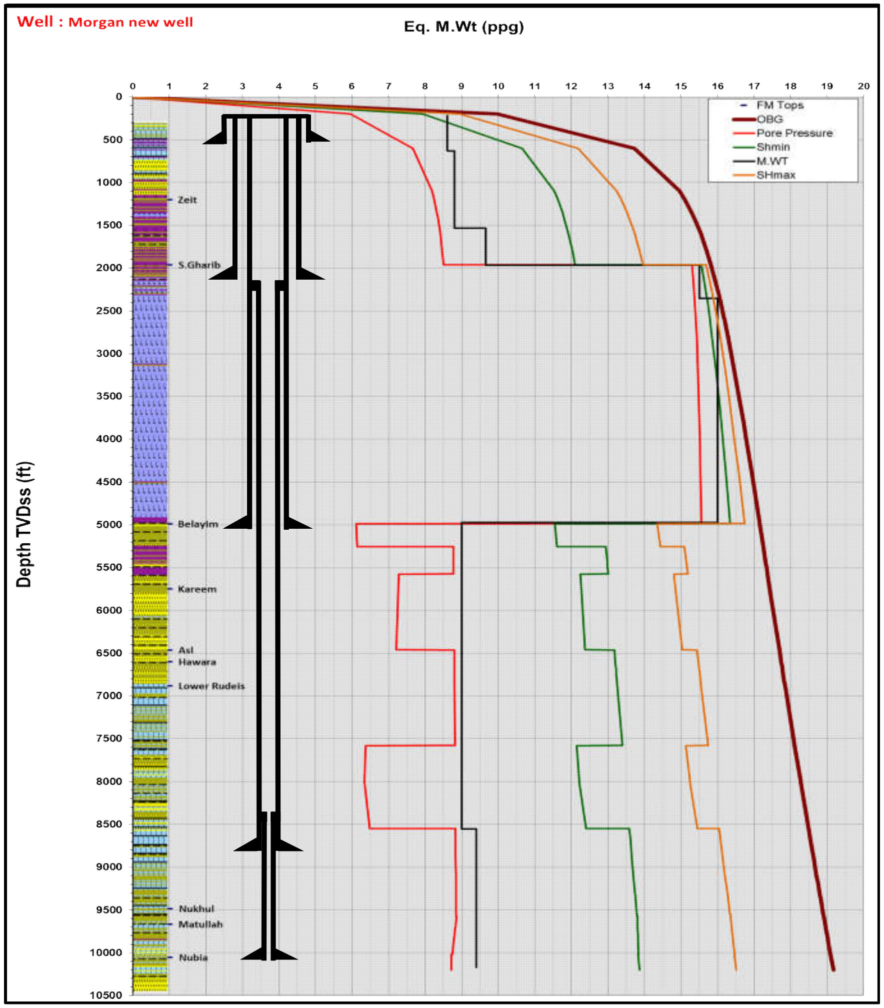
Pore Pressure and Horizontal stresses variation





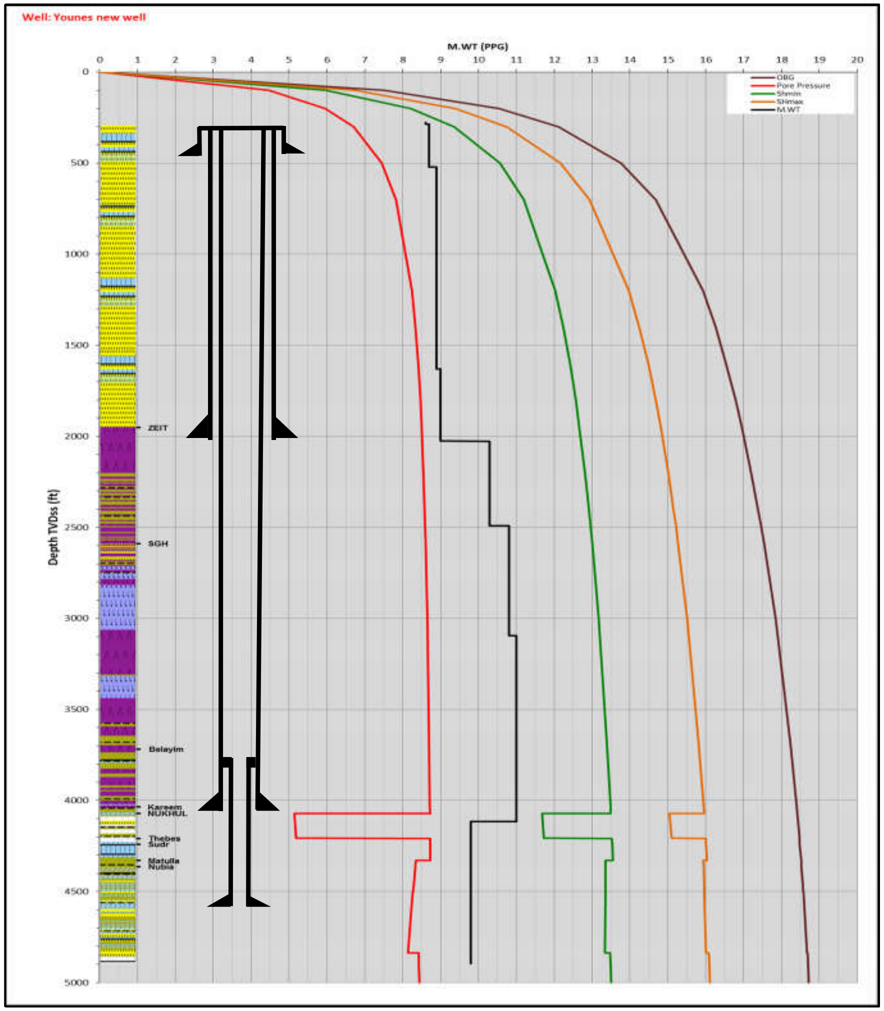
2 models including vertical stress, Pore pressure ,Shmin and Shmax values in the 2 fields were created after basin modeling study. Pore pressure calculations using sonic logs and the well incidents (water flow) in the previous wells. Eaton's equation was used to calculate the Shmin. This difference between the 2 wells in the pore pressure and the principal stresses resulted in different well design and casing criteria

Morgan Success story



- Overburden pressure for the new Morgan well shows low overburden gradient with gradual rate of increase with depth
- Hydrostatic pressure = 8.9 ppg calculated from the brackish water pressure gradient 0.465 psi/ft
- Morgan well shows high pore pressure in the South Gharib formation due to the compaction disequilibrium which proved by the salt water flow problems while drilling the offset wells, this interval had to be isolated in a separate hole with separate casing ,Some regression in pressure due to the depletion of the reservoirs
- After calculating the Horizontal stresses, mud weight window in each hole should be higher than the highest pore pressure and lower than the lowest Shmin values
- Decreasing the mud weight window in the Evaporates due to increasing the pore pressure
- New casing strategy has been designed based on the new study
- The new well was drilled using the designed mud weight without any well control incidents and with minimum Non Productive Time in the field

Younes Success story



- Overburden pressure for the new Younes well shows high overburden gradient with a significant increase with depth (affected on the sand fracture gradient)
- Hydrostatic pressure = 8.6 ppg calculated from the brackish water pressure gradient 0.465 psi/ft
- Younes well shows normal pore pressure along all the well even in the South Gharib formation due to the compaction equilibrium which evidenced by the safe drilling operations using low mud weight in the offset wells, Some regression in pressure due to the depletion of the reservoirs
- After calculating the Horizontal stresses, mud weight window is almost constant along the well path except the changes in the reservoir due to the depletion based on the stress path
- Wide mud weight window along the whole well path due to the normal pore pressure
- Casing strategy has been designed based on the new study
- The new well was drilled using the designed mud weight without any well control incidents and with minimum Non Productive Time in the field

Conclusions

- The tectonic evolution of the Gulf of Suez has a great impact on the stresses values in each field
- The field location in the basin affect on the sedimentary pattern of each formation
- Basinal fields have thicker and different evaporates facies than the peripheral ones
- Compaction disequilibrium is one of the most effective factors resulting in the overpressure zones in the Gulf of Suez
- The rate of deposition and the burial history has a direct impact on the stresses values in the field
- Optimum selection of the analogue data will affect on the well design and the casing points in each separate well
- Building a burial history combined with the offset drilling data is the optimum starting point that should be used in the wellbore stability studies which affect on the Non drilling surprises and the safety margin of the well drilling operations

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