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Dynamics 3D/ 4D Modeling of Natural Gas Reservoir: Resolving the Complexities of the Niger Delta Formations for Effective Gas Production.

Ukpohor Theophilus, Delta State University, Nigeria

INTRODUCTION

The Niger Delta located at the southern flange of Nigeria has been discovered to be one of thew highest reserves of natural gas in the world with a proven reserves of 124TCF, it is now being termed as a gas province laced with oil. Although oil production has being the priority in this province over the years, with new gas markets the oil industry is "metamorphosing" into a gas industry.

Hydrocarbon reserves were first discovered in the Niger Delta as long as a century ago in 1908 with a little understanding of the province. Exploration activities were carried out on blind data at the time. With the improvement in seismic techniques in early 1950 interesting structures were detected and more data provided to support early literatures. Yet there were still a lot of questions about the formation and structures inherent in the delta.

THE NIGER DELTA

The Niger Delta has its genesis in the Benue-Abakaliki Trough, which originated as an arm of the Triple- junction rift ridge system that initiated the separation of South America from Africa in the Aptian/Albian. The three arms of the system opened up at different times and different rates. In the South Atlantic the opening started in the Mid-Aptian by crustal stretching and downwarping accompanied by the development of coastal evaporite basins. By lower Albian it had reached the Gulf of Guinea and extended northeast to form the Benue- Abakaliki Trough. By early Eocene the Benue trough was fully developed accompanied by other tectonic activities lead to the formation of the Niger Delta at the south as a delta to the Atlantic Ocean.

The thick wedge of the Niger Delta sediments can be considered to consist of three units. The basal unit primarily compose of marine shales is called the Akata formation. This unit also comprises some sand beds, which are thought to be continental slope channel fills and turbidites. The Akata formation ranges in thickness from 600 to probably over 6000 meters. The overlying paralic sequence, forming the Agbada formation consist of interbeded sands and shales with a thickness of 300 up to about 4500 meters. The Agbada formation is built up of numerous offlaps cycles of which the sandy parts constitute the main hydrocarbon reservoirs and the shales the caprock, the topmost unit, the Benin formation is composed of fluviatile gravels and sands. This unit is thickest in the central area of the delta (2100m) where there is maximum subsidence of the basement.

In the building of the Akata formation, rapid sand deposition along the delta edge on top of the undercompacted clay has resulted in the development of large number of synsedimentary gravitational faults. These so-called “ growth faults” are also well known from the US Gulf coast. The spacing between successive growth fault decreases with an increase in the rate of depositional slope or an increase in the rate of deposition over the rate of subsidence.

The name growth fault, derives from the fact that after their formation the fault remain active and the thereby allow a faster sedimentation in the downthrow relative to the upthrow block. The ratio of the thickness of a given stratigraphical unit in the upthrow block is termed the growth index which in Nigeria can be as high as 2.5. The fault throw at the level of the Akata formation is often as large as several thousand feet. The enhanced sedimentation along the growth fault causes a rotational movement, which tilts the beds towards the fault. In this way anticlinal, so-called “ rollover” structures are formed along the faults. Some 25 oil fields in the Niger Delta are basically unfaulted. More common are fields in which one or more additional south hading fault intersect the structure formed by the main fault. Some 70 fields are of this type. About 10 additional fields are simple anticlines with one or more antithetic faults. About 20 fields in the coastal region of the Nigeria Delta are much more intensely faulted than the above fields. Their fault pattern is of collapsed crest type with a series of closely spaced growth faults and a series of antithetic faults.

The reservoir quality of the sands is strongly dependent on the deposition environment and the depth. Many reservoirs consist of a single barrier bar or point bar development. Reservoir sands thicker than 15 meters are usually of a complex nature, consisting of a superimposition of sands deposited in the same or different sedimentary environments. Laterally many reservoirs are heterogeneous. A common occurrence is a barrier bar cut

by a distributary channel at the same stratigraphic level. Reservoir permeabilities are variable, but generally high – as high as –several Darcies.

APPLICATION O F 3D /4D MODELING

The effective production of this natural gas province will need an evaluation tool that dynamically resolves complexities of the formations that lay the reservoirs. One that will display the structural geology of these reservoirs gives a solid database of reservoir characterization. A tool that can build a static earth model that from which a datum is drawn for geological simulation. 3D / 4D modeling today provide this tool. With in-depth visualization of the Niger Delta it complexities is being resolved.

Having all your seismic interpretation tools integrated on one database facilitates 3D modeling with all data obtained from the field such as seismic data, logs, production information, core descriptions and analysis results and geological as well as other interpretations acting as ingredients for effective model building. Thus models built from a combination of seismic data, geologic information and petrophysical interpretation.

Morealso, the recent application of 4D modeling i.e. Time lapse 3D surveys over producing reservoir have proven quite effective for reservoir monitoring. It enables the identification of dynamic reservoir behavior by interpreting the observed differences over time, such as those induced by production.

Therefore full optimization of gas reserves in the Niger Delta, 3D/4D modeling is intensively employed in resolving the complexities of the Niger Delta for effective production. Application covers wide geological issues and areas of ambiguity that could not be resolved by the employment of 2D seismic modeling.

The structural geology of the reservoir in the Niger Delta has been poorly understood with application of 2D models. The simulation of geologic models in 3D effectively handles the problems of complexities. Reservoir modeling software incorporates technologies that provides three dimensional workspace where all database are viewed and interpreted stored in the true perspective of geospatail relationship. The visual linkage of subsurface events, such as amplitude effects and porosity attributes had advanced the ability to analyze structural and stratigraphic phenomena.

Using depth imaging, we could actually visualize the structure of the block. Consequently, maps in the three dimensional workspace enhance the delineation of stratigraphic features and subtle faults trends. Attribute analysis unlocks clues from

seismic data to support and enhance the interpretation, often removing the bias inherent in traditional interpretation processes.

CASE STUDY ANALYSIS

The Alpha* field is situated some 70 km south of Warri in the southeastern part of OML 46. It lies in the southern part of the coastal swamp-1 depobelt and forms part of the Ogbotobo-Beta*/Clough creek macrostructure. It was discovered in 1967. The production of oil from the field was originally based on 2D seismic models, which provides a lot of ambiguity and limitations. Major structures were not fully comprehended while a lot of by-pass oil was not discovered. Gas reserves within the field were poorly developed due to poor interpretation tools to decipher the gas zones from the oil zones.

3D seismic data acquisition were carried out on the field in 1988 which covered approximately 57 sq. km. Data quality was considered good down to about F2.0 level (approximately 2.0 seconds) thereafter, data quality deteriorates appreciably resulting in very poor fault definition at depth.

A structural configuration was printed from a combination of the seismic data and various logs. The structure was an elongate, NW-SE oriented, conjugate K – type fault system with the main antithetic fault marking the break from the more-or-less steeply dipping open structure in the southwestern flank to the relatively low dipping anticlinal (rollover/ faulted) part of the structure which constitutes the main Alpha accumulation. This rollover features was remotely controlled by the Beta field boundary fault. The Alpha field boundary fault on the hand seemed to have simply mimicked this Beta boundary fault. The relative and uneven displacements across the Alpha fault gave rise to a more-or-less continuos clockwise rotated appearance of the entire structure as observed on seismic sections, while the antithetic fault seems to have been triggered-off as compensatory fault that created accommodation space at the crestal part of the field during sedimentation. Beyond the antithetic fault, towards the southwest, the Alpha features a continuously dipping and open structure that shows no closures, especially at the main reservoir levels. In the northwestern part the structure dips into a saddle as the fault coverage.

The modeling of the field was able to produce more information on the gas reserves that were yet drilled. Time- lapse 3D survey carried out on the filed 10 years after initial 3D survey revealed more information on the field to enhance effective production of the field which is majorly a gas field.

OTHER APPLICATIONS

Of great importance, also is the application of 3D / 4D in the evaluation of candidate reservoirs for underground storage of natural gas, a conservative method of harnessing natural gas that is to be flared. A proper evaluation of the reservoir must be carried out to optimize it full storage capability potentials. The seal strength and water influx rate must be determined alongside with other reservoir characterization that will enhance storage.

* Original field names are classified

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