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The Study of 3d Seismic Velocities on Depth Conversion and Reservoir Volumetrics in "Akos Field", Onshore Niger Delta

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ABSTRACT

The study investigated 3D seismic velocities as playing a vital role in accurate depth conversion and volumetrics using the "Akos field" as a case study to be revisited for previously bypassed information as well as enhanced information on estimation of target depth and volumetrics. The petrophysical properties revealed a porosity that ranged from 20% to 30%.. Main oil accumulations lie between 6500ft subsea and 11500ft subsea at the central part of the field. Various velocity models were applied to depth conversion and volumetrics and the most suitable with respect to volumetric output, closeness to zero offset, "fit to well" and formation dependence was identified. This study proved to be useful in the creation of a reference material for marginal field operators and operator of fields that are being revisited.

INTRODUCTION

Velocity has largely been regarded as isotropic in the locating and planning of wellbores. This may have led to discrepancies and inaccuracy in determining the depth of target reservoir sand bodies within a 3D seismic project area. On the contrary most geological formations with distinct layers of sedimentary material can exhibit electrical anisotropy; electrical conductivity in one direction (e.g. parallel to a layer), is different from that in another (e.g. perpendicular to a layer).

Seismic anisotropy is the variation of seismic wave speed with direction. This is an indicator of long range order in a material, where features smaller than the seismic wavelength (e.g., crystals, cracks, pores, layers or inclusions) have a dominant alignment. This alignment leads to a directional variation of elasticity wave speed.

Measuring the effects of anisotropy in seismic data can provide important information about processes and mineralogy in the Earth; indeed, significant seismic anisotropy has been detected in the Earth's crust, mantle and inner core. An appropriate analysis of these variations in seismic velocities (anisotropy) can be applied to aid in accurate determination of target reservoir sand bodies, field appraisal and development, well planning and placement, optimal trajectory of well and estimation of reservoir volume.

Aim and Objectives of Study:

i. The study is aimed at bringing out the benefits of velocities especially in the conversion of subsurface travel time to depth.

ii. To propose methods that may lead to reduction or elimination of inaccuracies in the determination target depth of drilling.

Study Area:

The research area is situated in the onshore coastal swamp depositional belt in the Niger Delta eastern part.Akos field is situated within latitudes 4° 19′ 00” N and 4° 50′ 00” N and Longitudes 6° 02′ 30” E and 7° 10′ 00” E.

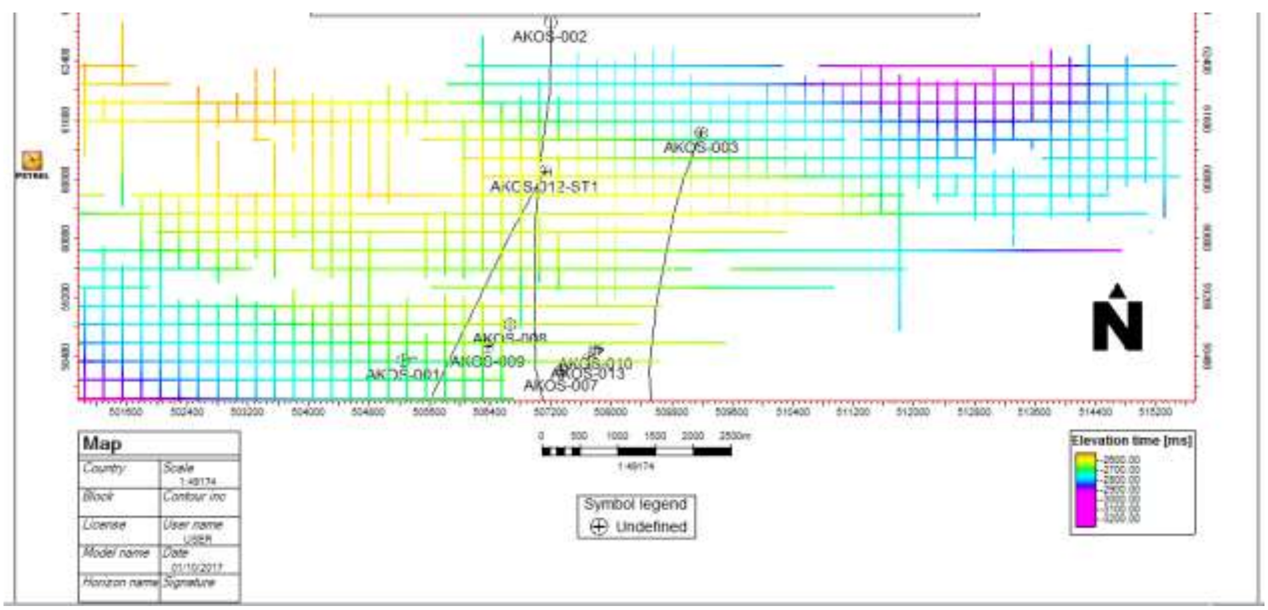

Fig 1; Location of Study Area.

It is located within the eastern coastal swamp of the delta and is part of a mega structure which is an elongated east- west trending anticline dissected by a series of major synthetic and antithetic faults.

METHODOLOGY

Nature/ Sources of Data

Data was obtained before and during drill of the wells. They include: Seismic Data set, Well data.etc

Method of Data collection

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 16
June 2018

Data Acquisition

Seismic data was acquired through the passage of acoustic waves into the subsurface and measurement of time where source and spread of receivers arranged in gridded array. The objective is to record the reflection signal which appears on the record as a curved event or wavelet **(**seismic trace**)** with variations in amplitude. Undesirable signals, known as noise, such as the direct waves which travel along the surface between shot points and receivers and the refracted waves which travel along the boundary of high velocity layers are also present. These may be attenuated during recording or by subsequent processing.

METHODOLOGY

Method of Data Analysis

Seismic Data Processing

The objective of seismic data processing is to improve signal-to-noise ratio (SNR), and improve the"resolution vertically" of the individual seismic traces by waveform manipulation so as to facilitate data interpretation.

The main objective of a seismic reflection survey is to obtain a regional structural geological control of a sedimentary pile whose rudimentary data have been provided by other geophysical methods (such as magnetic and gravity) and outcrop sections. Generally, seismic method is used at different scales of investigation ranging from the mapping of sedimentary basins, mapping of fault patterns within producing fields; mapping depositional packages to ascertain sand and pore fluid distribution and more detailed actual depth-controlled seismicdata acquisition (Vertical seismic Profiling -VSP) from drilled wells.

Generation of Well logs

After a section of the well is drilled, logs are obtained by lowering a sonde or tools attached to a cable or wire to the bottom of a well bore filled with drilling mud. Electrical, nuclear or acoustic energy is sent into the rock and returned to the sonde or are recorded from the rock and measured as the sonde is continuously raised from the bore bottom at a specific rate. The well is logged when the sonde arrives progressively at the interval to be investigated.

Formation water, porosity, permeability, radioactivity are rock properties which affects logging and the types of logs to be obtained. "Wireline logs" can be divided into three groups;

a. Lithology logs (spontaneous potential, gamma ray).

These logs discriminate different lithologies

b. Resistivity logs (induction, electrode)

They can be also used to delineate reservoirs and in combination with porosity logs and to calculate "hydrocarbon saturation".

c. Porosity logs (sonic, neutron, density).

These are logs used to identify lithology, calculate porosity, and differentiate oil from gas.

RESULTS AND INTERPRETATION

Presentation of Data

Three full stack seismic data cubes with 14 wells were available in Akaso field. Checkshot data was available for six wells AKOS-001, AKOS-003, AKOS-004, AKOS-008, AKOS-009 and AKOS-012. Well tops were available for all the wells and producing levels in this field and were quality checked. Well logs for all the fourteen wells were also available in ASCII format.

Data Analysis

Seismic interpretation

(A) Well to Seismic Tie AKOS-002 had a complete dataset, i.e. checkshot, sonic log and density log, required for a well to seismic tie and gave the most reliable wavelet. All other wells were adjusted with respect to AKOS-002 for horizon identification.

The logs were calibrated from depth domain to time domain using checkshots and sonic logs was used for wavelet estimation. The reflectivity calculated using calibrated time logs, which when convolved withthe wavelet, gives a synthetic seismogram. Detailed wavelet estimation was carried out for AKOS-002 well and different estimation windows were tested. Wavelet for final well to seismic tie was estimated between 1900-2680ms. The well to seismic tie is shown in (Figure 1).

A good well to seismic tie was achieved at the well and a reliable wavelet was extracted, indicated by the shape of wavelet, smooth amplitude spectrum and reasonable predictability value.

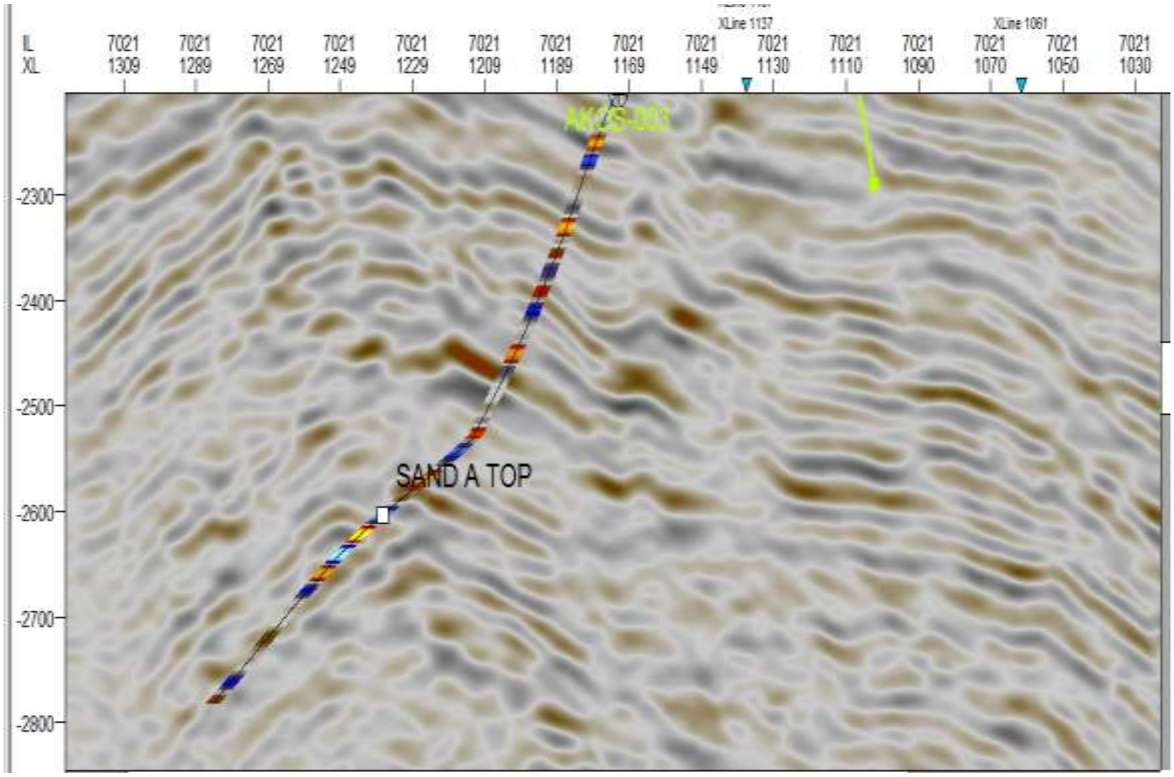

Figure 1 Seismic to well tie of Akos 002

(B) , Horizon Interpretation

The well log correlation is shown in Figure 4.3. The field is producing from 24 pay zones but few of these are very close to each other as shown in Figure 2. For this reason, interpretation was done on the major reservoir as shown below.

Horizons were picked by seeded 3D auto tracking and then a quality check was done on every fifth Inline and crossline. These horizons were then taken to structural framework and edited before depth conversion.

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Volume 05 Issue 16
June 2018

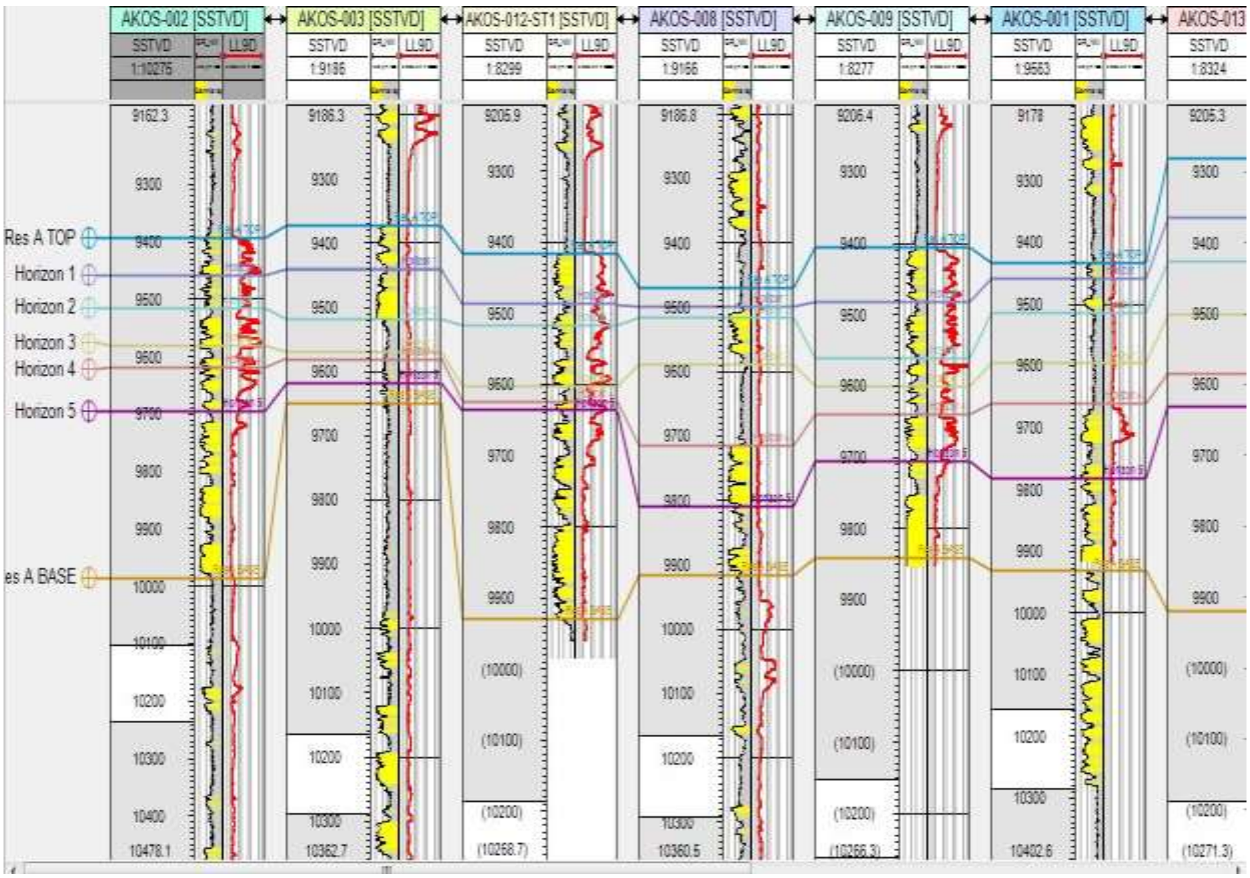

Figure 2: well log Correlation across wells

C, Fault Interpretation

Fault interpretation was done in two phases; initially faults were interpreted on every 10th or 20th Inline, depending on complexity of area, and were not assigned. After which, the horizons were interpreted Dip and Azimuth were generated and faults belonging to the same fault segment were assigned to one fault. If an Inline was in the strike direction of a fault, then it was picked in the crossline direction. These faults were then checked and adjusted with the help of fault grids coming from the structural framework. A seismic line passing through AKOS-002 well with assigned faults is shown in Figure 3.

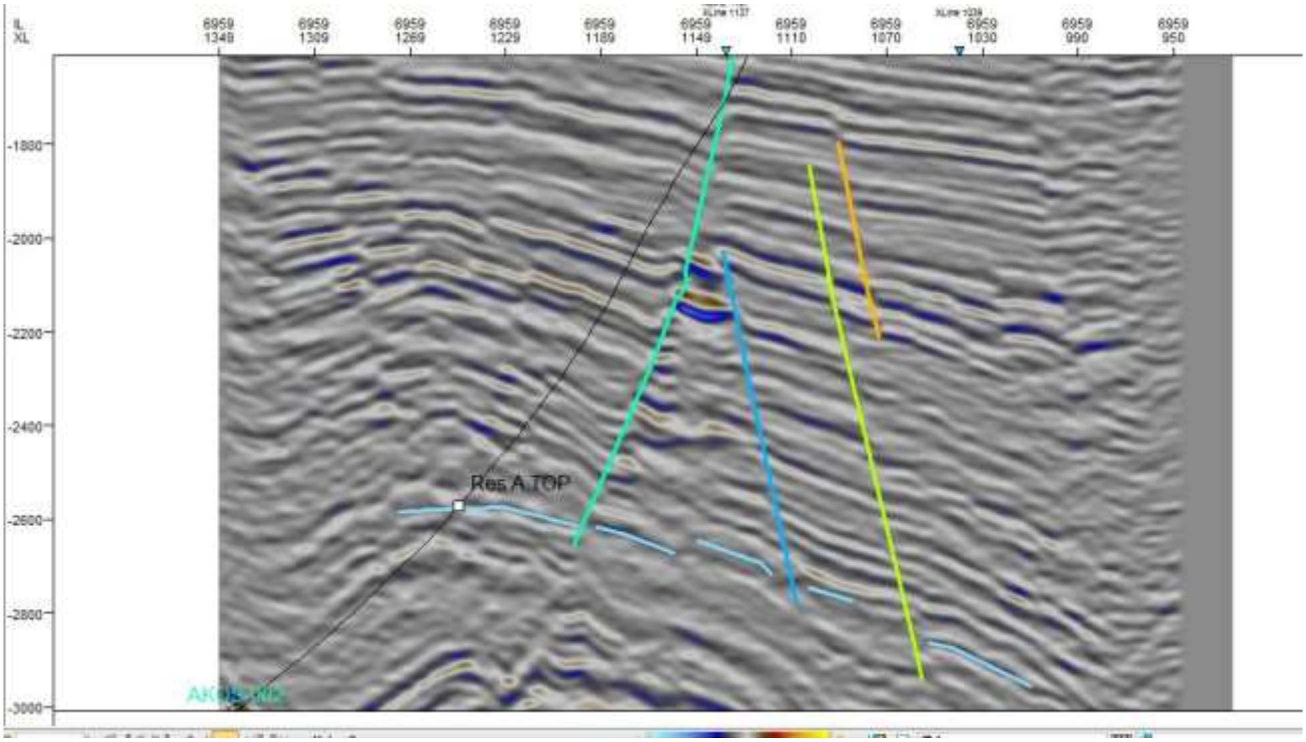

Figure 3: Fault map

Depth Conversion

Depth Conversion involved a few stages. Each stage will be explained in subsequent sub-headings. The figure below shows the time surface map and the time map respectively before conversion to depth.

i. Reference Checkshot

Based on the available data; 6 wells in the Akaso field have assigned checkshots with no original checkshot reports available at the time of this. Available wells with checkshots are AKOS-001, AKOS-003, AKOS-004,AKOS-010, AKOS-011. Observation based on individual degree of well deviations, input log conditions especially sonic and density logs, quality of the checkshot information and finally the well to seismic tiesupports the choice of well AKOS-003.

ii. Velocity Function

The next step was extracting a function in order to calculate the average velocity against two-way time selected for well AKOS-003 (Figure 4)

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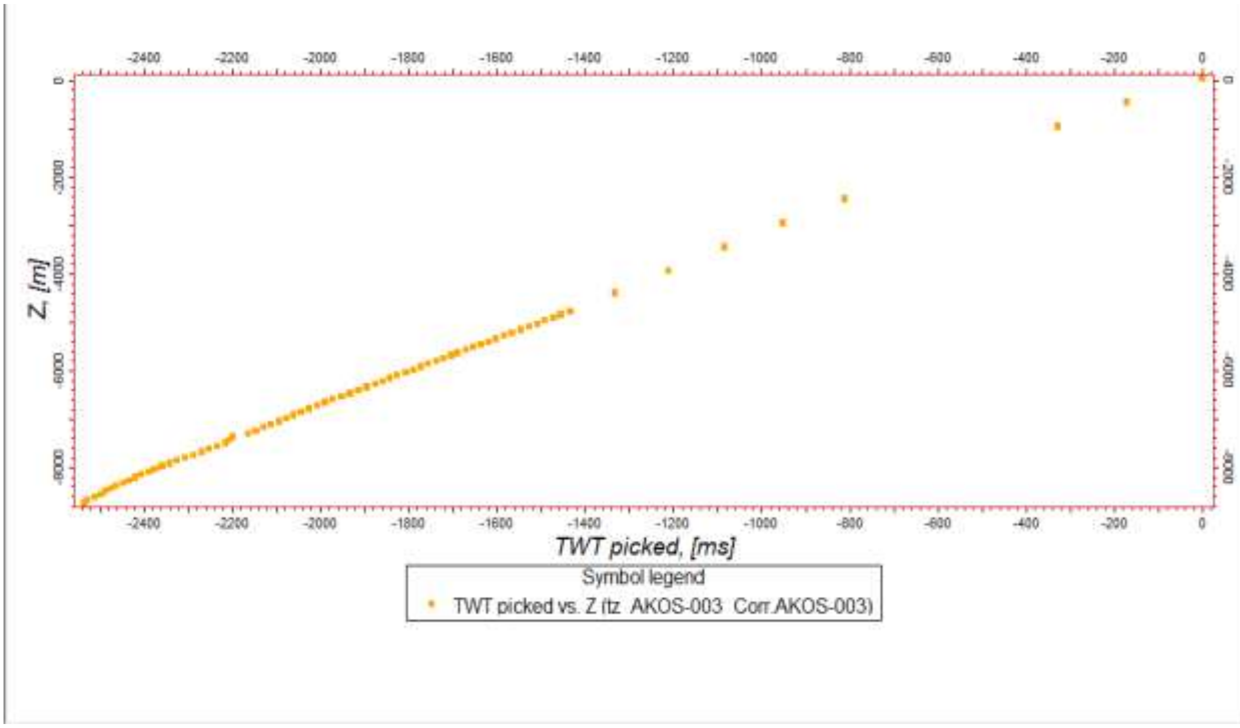

Figure 4 Average velocity against two way time TWT

iii.Average Velocity Field

Based on AKOS-003 average velocity function a 3D average velocity field was generated, this was the basis creation of velocity models.

Generation of velocity Models

Velocity models can be built based solely on or from a combination of checkshots, VSPs, sonic logs or seismic stacking velocities. Depending on the information available, the method of building a velocity model can vary (using interval velocities, average velocities, layer cake model, V 0 -K method, models based on geostatistical methods ...). in this case sonic and checkshots were used. Checkshots were useful in calculating the average velocity. Using the petrel software, three velocity models were generated.

I. Model V=V0 (Interval Velocity)

This makes use of the average velocity over the given interval and is also supported by the equation:

Vint = Delta Z/Delta T

Where Z= Reference depth

T= One way time OWT

- It doesn't give room for abrupt velocity changes

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Volume 05 Issue 16
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- May yield poor stacking velocities unless in areas where velocity is mostly constant

II. Model V=V0+KZ

This assumes that velocity varies linearly with depth (due to compaction).

Vinst = V0+KZ

Where V0= Reference velocities at mean sea level

K= Velocity Gradient

Z= Reference depth

Vinst changes in relation to gradient.

- Also called layer based model
- It can be pretty accurate if V0 value is constant
- It assumes that velocity increases with depth as a result of compaction

III. Model V=V0+K(Z-Z0)

This is is set up to reference the formation top

V0= Instantaneous interval velocity at the top of the formation

Z0= Depth at the top of the Formation

Z= Depth

- This model is a modification of the second model making it formation (geology) dependant
- created a good fit at wells

IV. Model V= V0+KT

V0= Reference veelociy

K= Gradient

T= Time

- Seems to give bogus results far from zero offset

The last step was to for depth conversion of interpreted horizons. The horizon depths were compared to the well top depths and uncertainties calculated.

Domain Conversion

A velocity model was generated to depth convert structural surfaces extracted from final structural model from and final interpreted faults into the time domain. Therefore, it is important to have the final structural model ready before domain conversion. After the initial main structural model was created and finalised in time domain, this velocity model was used to convert relevant data for the depth domain, which will then be used to re-create the structural model. The Velocity model extends beyond the Akaso structural model in order to avoid any marginal distortions

Summary Depth Conversion results are shown below.

- Model V=V0 (Interval Velocity

- Model V=V0+K(Z-Z0)

Copy of Surface	Well	X-value	Y-Value	Z-value	Horizon After	Diff after	corrected?
	AKOS-004	499790.8	62407.1	-9322	outside		No
	AKOS-12-ST1	506885.8	60452.2	-9414.82	-9412.61	2.21	No
	AKOS-013	507693.4	58387.6	-9281.64	-9280.75	0.89	No
	AKOS-001	505296.8	58322	-9433.82	-9432.45	1.37	No
	AKOS-002	507016	60545	-9393.24	-9391.32	1.92	No
	AKOS-009	506371.7	58547.2	-9405.46	-9404.92	0.54	No

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 16
June 2018

	AKOS-007	507338.1	58202.1	-9393.1	-9392.99	0.11	No
	AKOS-010	507860	58458	-9246.48	-9245.32	1.16	No
	AKOS-003	508812.3	60264.9	-9372.4	-9369.77	2.63	No
	AKOS-008	506662.2	58851.9	-9469.98	-9481	0.86	No

Table 1 Depth conversion results for V0+K(Z-Z0)

i. Domain Conversion Quality Control:

Average velocity field are checked against borehole checkshot information in a well section display. In this stage the velocity field must have a complete match with the source of the velocity calculation. Adding to that the converted surfaces to depth must show a reasonable proximity to the related well tops.

Structural Modelling

Structural modelling was done in two stages, firstly the model was built in time by using interpreted horizons and faults. These horizons and faults were adjusted to make a structural model that is geologically plausible. This also provided a way of checking the interpretation, especially the faults. The structural model is then converted into depth. Individual surfaces are not tied to each well therefore they need calibration with respect to well markers. The process was started by tying depth surfaces with markers at each well, this was sometimes not possible at a particular well as it would change the structure abruptly. This was especially the case for those tops which are close to the fault zone. Most of the markers tied to the wells with the exception of a few that didn't tie. . The main QC for the depth calibration was to see if the depth surface before and after calibration is following the same trend. A comparison between depth surface before and after calibration is shown in Figure 4.8 and Figu

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Pillar Gridding

To get out the shape of the reservoir, an external grid was created. Grids was put together to give"10,000" cells (the grids divided the model into cells), which can allow flow model to be done (fig). The grid cells have a rock type a value of porosity, permeability, water saturation and NTG. It means generation of structural model done in the process of pillar gridding preserves a small amount of features from "well logs" and "seismicdata". Pillar gridding make it posible to identfy tops, middle, and base of structural model. (fig).

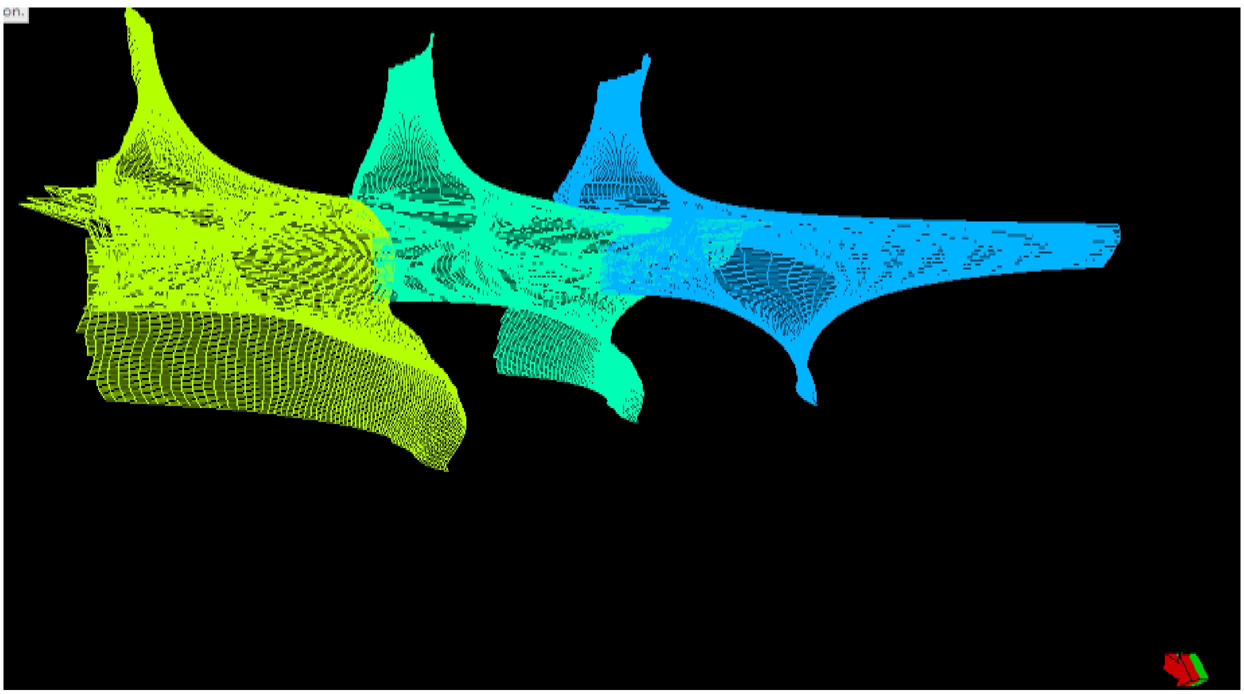

Figure 5: Pillar grids of model

CONCLUSION

The geological setting is the eastern part of the Niger delta. The Niger delta being a typical wave and tidal dominated delta located on the Atlantic side of Africa (Doust and Omatsola 1990). The key stratigraphic units are the Benin, Agbada and Akata formation.

Data base included well tops, well logs, checkshot etc. well tops were available for all the wells and producing levels in this field are quality checked. Calibration from time to depth domain were aided by the availability of the checkshots and sonic logs. Horizons were picked by 3D autotracking and faults were interpreted on every tenth to twentieth inline depending on the complexity of the area. Three velocity models were applied;

The model V=V0+KZ

The model,V = V0

The model, V=V0+K(z-z0)

The model V=V0+KT

The aim of the various velocity models was to aid accurate conversion from time to depth with a target of nearest to zero offset and to observe the effects on the corresponding volumetrics and the pay zones and general benefits.

From the depth conversion results in the previous chapter, the model V=V0+K(Z-Z0) produced the results which appeared to be most accurate and closest to zero off set when compared with the Well tops. In the volumetrics it provided the highest stock tank oil in place values. The velocity gradient in this model tends to be formation by formation preventing inaccuracy.

Petrophysical interpretation was then loaded for all the wells. Petrophysical analysis was done using standard interpretation techniques to derive porosity, permeability, net to gross and water saturation

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