International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Research Article

PETROPHYSICAL ATTRIBUTES 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%. Correlation of the wells revealed a lot of structural complexities within the field because of differences between depth and field prognosis. The presence of a sidetrack was noted at well 12 being situated close to a fault with considerable sealing properties. 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 may prove 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.

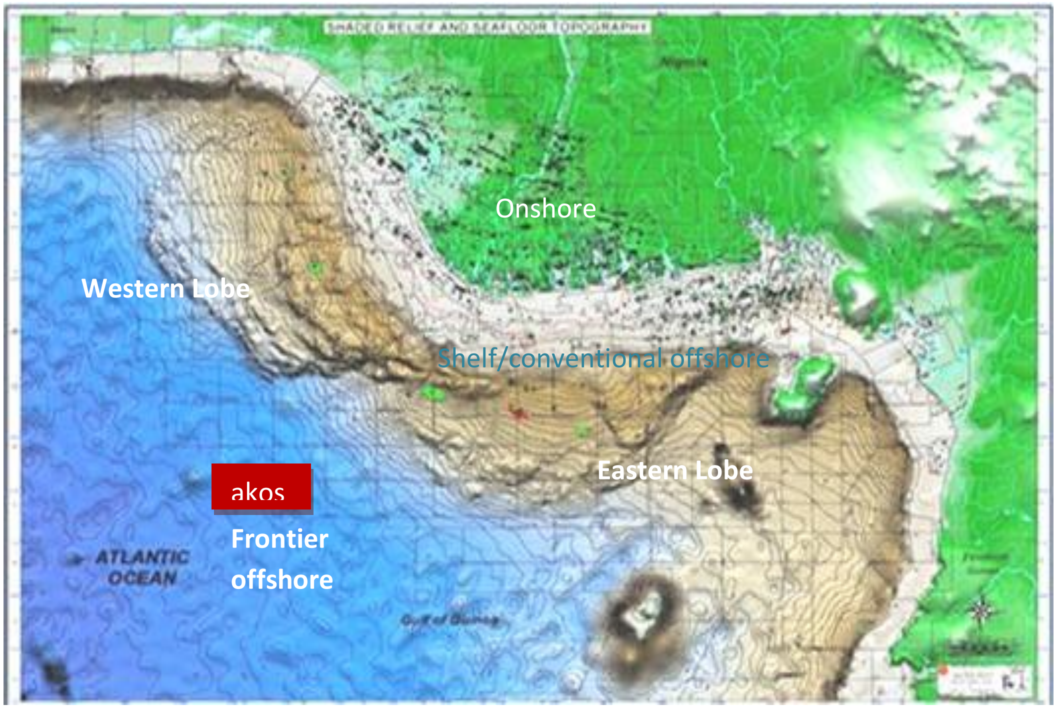

Figure 1: Location of study area within the Niger Delta

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

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. The field is situated in the coastal swamp of the eastern Niger delta. The Niger delta is an arcuate shaped wave and tide dominated prograding deltaic system. It is one of the world's largest deltas located in the gulf of guinea on the west coast of central Africa extending three hundred (300km) from apex to mouth.

LITERATURE REVIEW

Extensive literature review and several paper presentations on this field and their adjoining areas have been documented by. However, their work involved the integration and interpretation of wireline logs, 2D and 3D seismic volumes/sections, cores descriptions, petrographic, correlation, sequence stratigraphic and biostratigraphic data sets. The Niger Delta, on the passive western margin of Africa, has long been recognized as a classic example of continental-margin structural collapse under sediment loading (Armitage *et al.,* 2012, Edwards, 2000; Rensbergen and Morley, 2000; Rensbergen *et al.,* 1999; Morley *et al.,* 1998; Morley, 1992; Khalivov and Kerimov, 1983 and Daily, 1976). It ranks amongst the most prominent and prolific petroleum producing deltas in the world, it therefore accounts for about 5% of the world's oil and gas reserves and about 2.5% of the present-day basin area on earth (Hooper *et al.,* 2002). The Niger Delta sedimentary basin was initiated in the Early Tertiary times (Doust and Omatsola, 1990).

Others who also have documentary facts on the Niger Delta include Etu-Efeotor, (1999); Soreghan *et al., (*1999); Cross and Lessenger, (1998); Soronnadi-Ononiwu. and Omoboriowo(2013); Omoboriowo and Soronnandi-Ononiwu, G. C (2011): Omoboriowo and Edidem (2011) Omoboriowo, A.O, Chiadikobi,(2012); Oyanyan and Omoboriowo (2012),); Amajor and Agbaire, (1989); Asseez, (1976); Weber and Daukoru, (1975); Weber, (1971); Frankly and Cordry, (1967); Short and Stauble, (1967); and Allen, (1970, 1965).

METHODOLOGY

Work Flow:

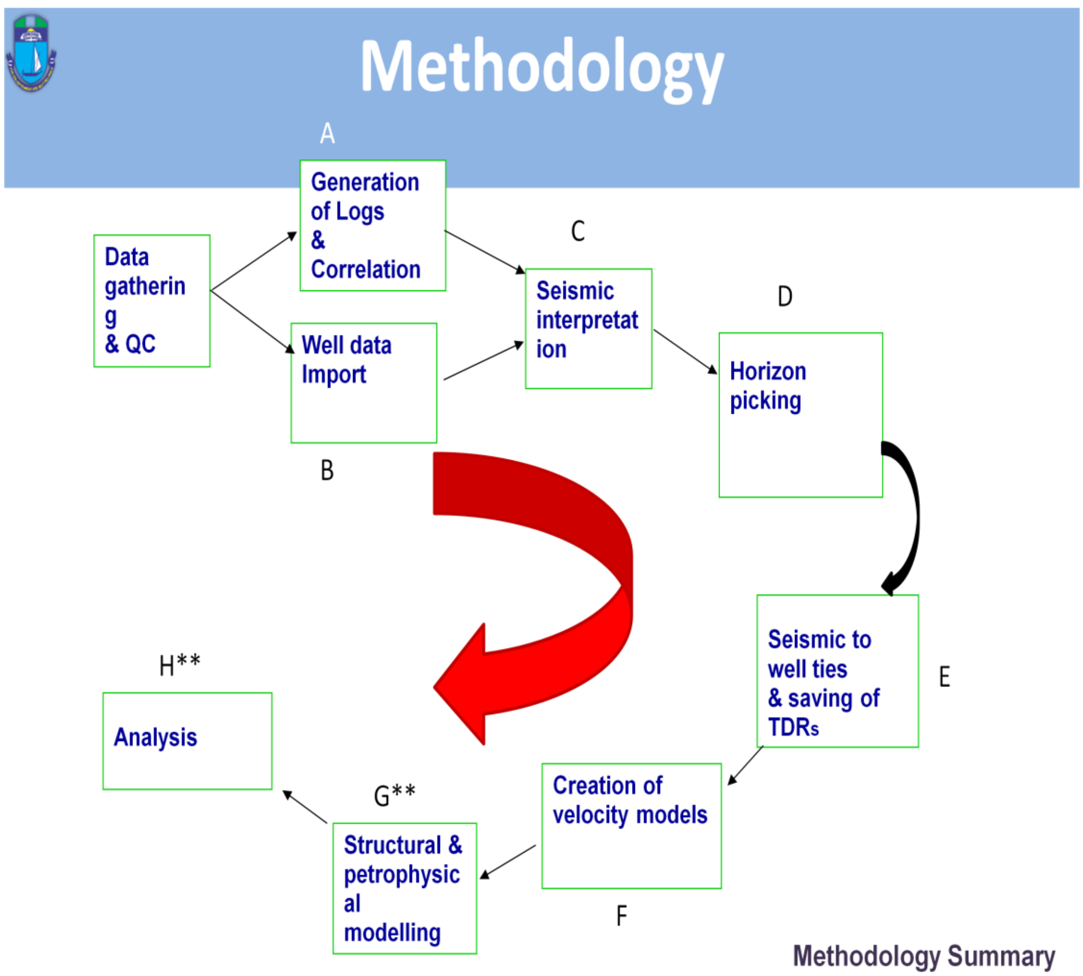

Figure 2: Work flow

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.

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.

Generation of Well logs:

After seismic interpretation has been carried out and confirmatory analysis to ascertain a "hydrocarbon" bearing reservoir at delineated depth, a well is drilled. Some information is revealed about the formation encountered in the drilled hole recorded as thedepth on logs. Logs provide information of vertical resolution of the survey area unlike the "seismic" section, which provide a good lateral resolution.

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;

Lithology Identification:

The identification of lithology was carried out before carrying out correlation of "reservoir" and correlation of wells, this was done as a result of the appearance of different log type and logs signature, from the "gamma ray" log, increase by the left side shows a sand unit while sharp decrease by the right side shows a shale unit from the resistivity logs. Indication given at sand unit simplify-hydrogen bearing and the intervals can be put into consideration.

Well Log Correlation:

Well log correlation was done using "Gamma ray", Resistivity, and Density log. The logs are activated and displayed in the well section, andorrelation is done using the "lithology log", the resistivity is to find out fluid contents available in the sediments i.e hydrogen or water. Stratigraphical beds" were used to identify parameter intervals (reservoir sands) and were correlated through out the field. Good comprehension of geology of the environment was needed here to pick the top base of the reservoir.

Horizon Interpretation:

Identification of prospective sand is from the gamma ray log available. In area without well control, strong reflection within the "seismic section" can be mapped. Time to depth conversion was done, and the corresponding structural maps produced. In PETREL, the 3D seeded auto tracking was used for picking horizon, in this project work.

Well To Seismic Tie:

Well to seismic tie of the hydrocarbon reservoir was achieved using check-shot data, which helps in observing how "seismic" character can be expected to be as the "stratigraphy" changes through the basin. It also helps in locating reflections and determine"seismic" events which are related in particular boundary surfaces. The Akos 003 is "tied" in"seismic data".

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 3)

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.

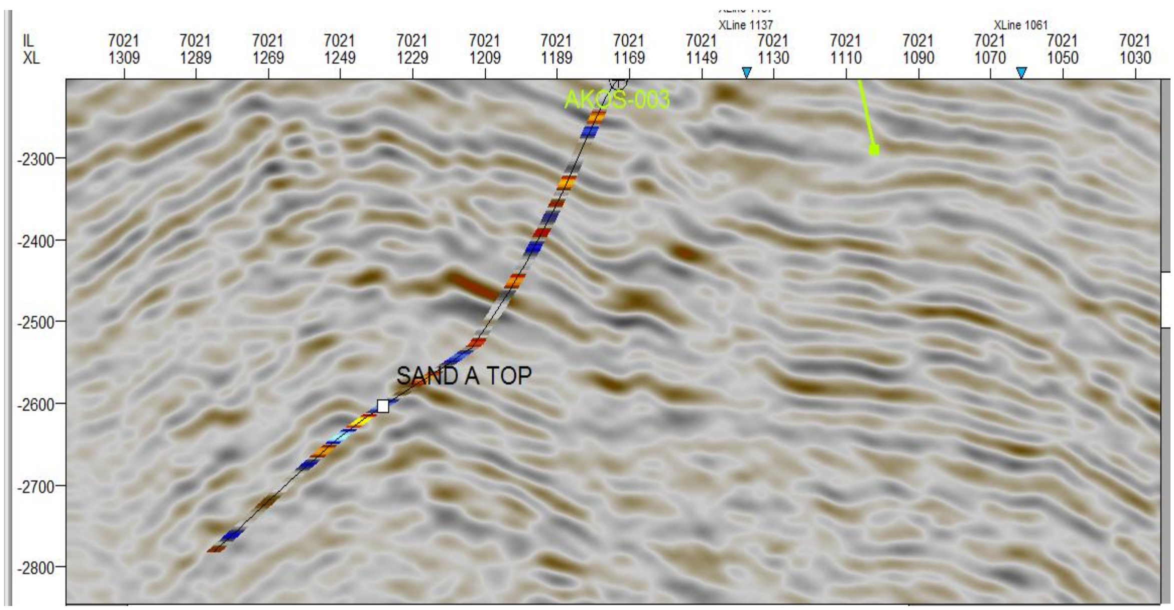

Figure 3: Seismic to well tie of Akos 002

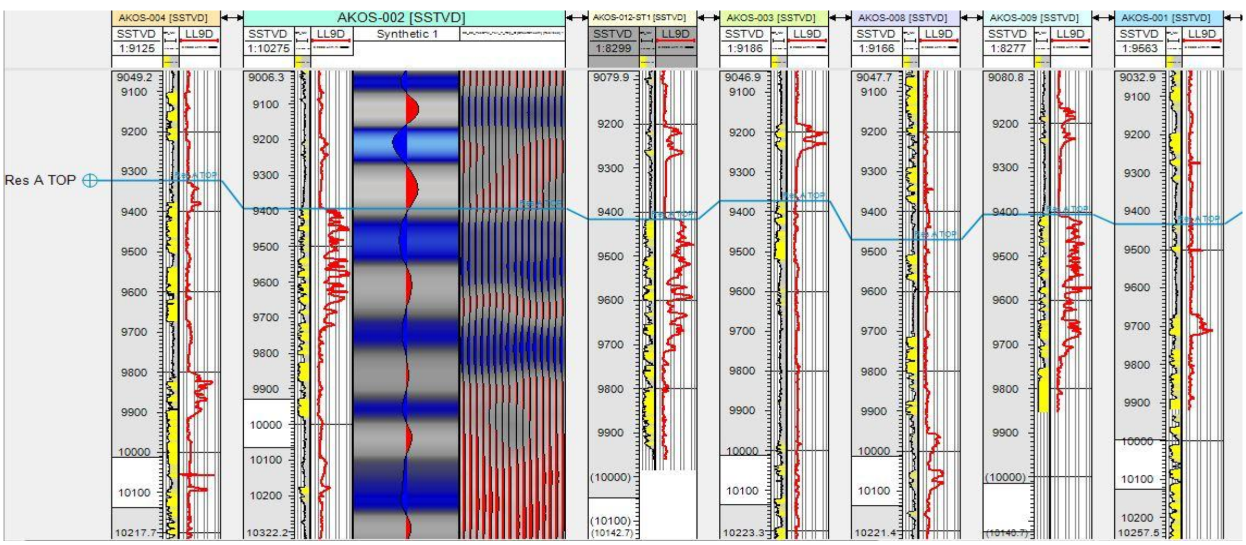

Figure 4: Synthetic Seismogram of Akos 002

i. Reference Checkshot:

Based on the available data; 6 wells in the Akaso field have assigned checkshots with no original checkshotreports 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

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.

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+KZ

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	-9412.58	2.24	No
	AKOS-013	507693.4	58387.6	-9281.64	-9280.77	0.87	No
	AKOS-001	505296.8	58322	-9433.82	-9432.48	1.34	No
	AKOS-002	507016	60545	-9393.24	-9391.29	1.95	No

	AKOS-009	506371.7	58547.2	-9405.46	-9400.27	5.19	No
	AKOS-007	507338.1	58202.1	-9393.1	-9392.26	0.84	No
	AKOS-010	507860	58458	-9246.48	-9245.34	1.14	No
	AKOS-003	508812.3	60264	-9372.4	-9369.75	2.65	No
	AKOS-008	506662.2	58851	-9469.98	-9469.09	0.89	No

Table 1: Depth conversion results for V0+KZ

PROPERTY MODELING

i. Facies Model:

Facies modeling is a means of distributing discrete facies throughout the model grid. The term facies is used either descriptively, for a certain volume of sediment, or interpretatively for the inferred depositional environment of that sediment. The reservoir also shows the occurrence of shale, colored grey and fine sand, colored brown. (Figure 5)

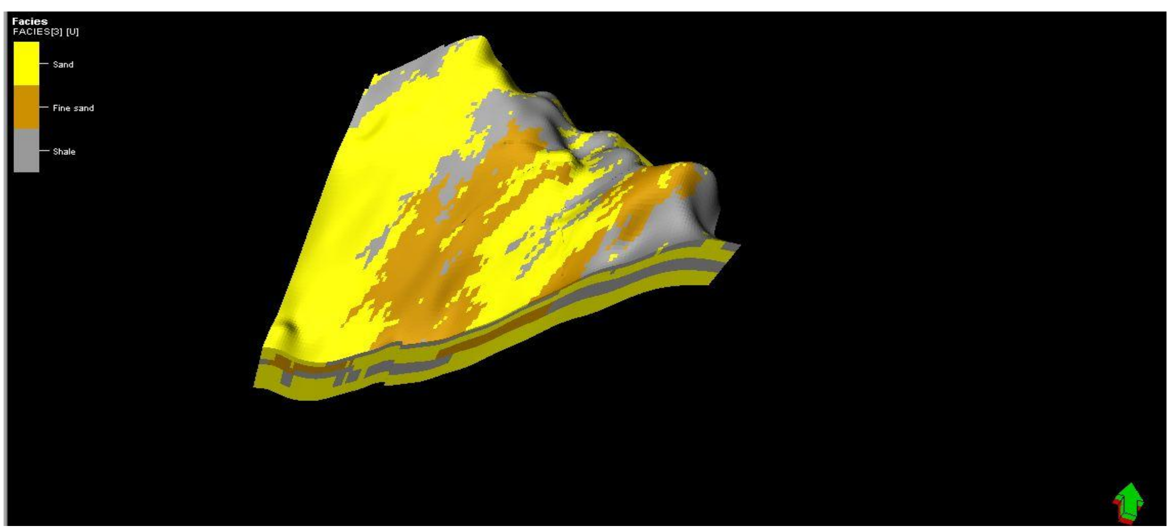

Figure 5: Facie model of Reservoir A

PETROPHYSICAL MODELS

i. Porosity Model

Porosity measures the void (i.e empty) spaces in the reservoir. The porosity of the roc played an important role when attempting to evalute the potential volume of water. 3D vie of the "porosity model" for the reservoirs shown in (fig 6). The modelled map gives a betterporosity distribution from the obtain porosity value (blue coloration) in the central region.

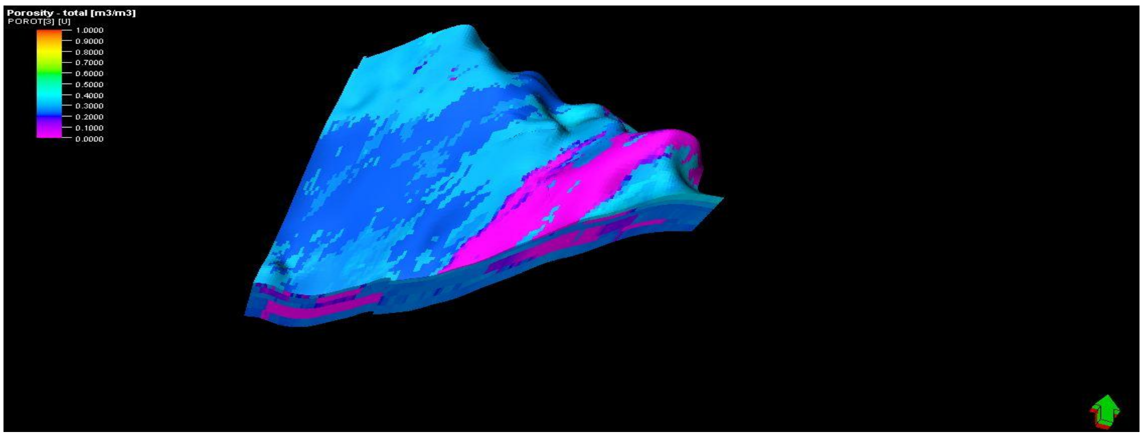

Figure 6: Porosity model of Reservoir A

i. Permeability Model:

Permeability is the important parameters that is generated in static model and utilized in dynamic situation. It defines directly the dynamic flow of a reservoir model. Permeability measures the "interconnectivity" of pore spaces. The permeability measurement techniques are limited to well locations.

ii. Oil Water Contact:

To differentiate hydrocarbon and water in the identified reservoir A and B, "resistivity" and "density" log were use. The areas ofreservoirs with "low density" and "high resistivity" signatures was accumulated by hydrocarbon, while high density gave water. Flow zones were used to get the "hydrostatic performance" of the reservor and to avoid over estimate of hydrocarbon-reserves. The delineated OWC for the reservoirwas at 9324m and 9500m populated on structural model for both "reservoirs".

V. Net to Gross:

Net to gross (NTG) is the measure of reservoir volume covered by hydrocarbon bearing rocks. It shows the amount of shale embeded in reservoir. Net-to-gross was modeled along reservoir in the wells using

Petrel software.

Table 1: below reveals high volume of hydrocarbon (red/ yellow coloration). The reservoirs denote a good prospect evident from their high net-to-gross value.

Vi. Petrophysical evaluation:

Different petro-physical propertiesporosity, permeability, Net-to-Gross, and Water-saturation was calculated and simulated.The average petro-physical properties were shown through the wells.

Well Name	porosity (ϕ)	permeability K(Md)	water saturation (Sw)	Net-to-gross (Ntg)
Akos 004	0.275264	186.9494	0.313474	0.423221
Akos 002	0.291306	591.8269	0.301028	0.736318
Akos 003	0.306998	331.4502	0.28083	0.318644
Akos 012	0.251915	100.2499	0.338373	0.474227
Akos 008	0.272421	143.4088	0.306802	0.497537
Akos 001	0.262948	186.5251	0.317611	0.847561
Akos 009	0.325964	345.9852	0.298781	0.170984
Akos 007	0.307749	139.0417	0.287443	0.00000
Avg %	28.68	253.17	30.55	43.35

Table 2: Summary of petrophysical results

- Model V=V0+KT

Item	STOIIP_in_oil_10_6_STB
Case V0+KT1	7630016.1290000
Case V0+KT2	7987445.8081716
Case V0+KT 3	7537908.6292716
Case V0+KT4	7346786.7153146
Case V0+KT 5	6855837.0922611

Table 3: STOIIP for V0+KT

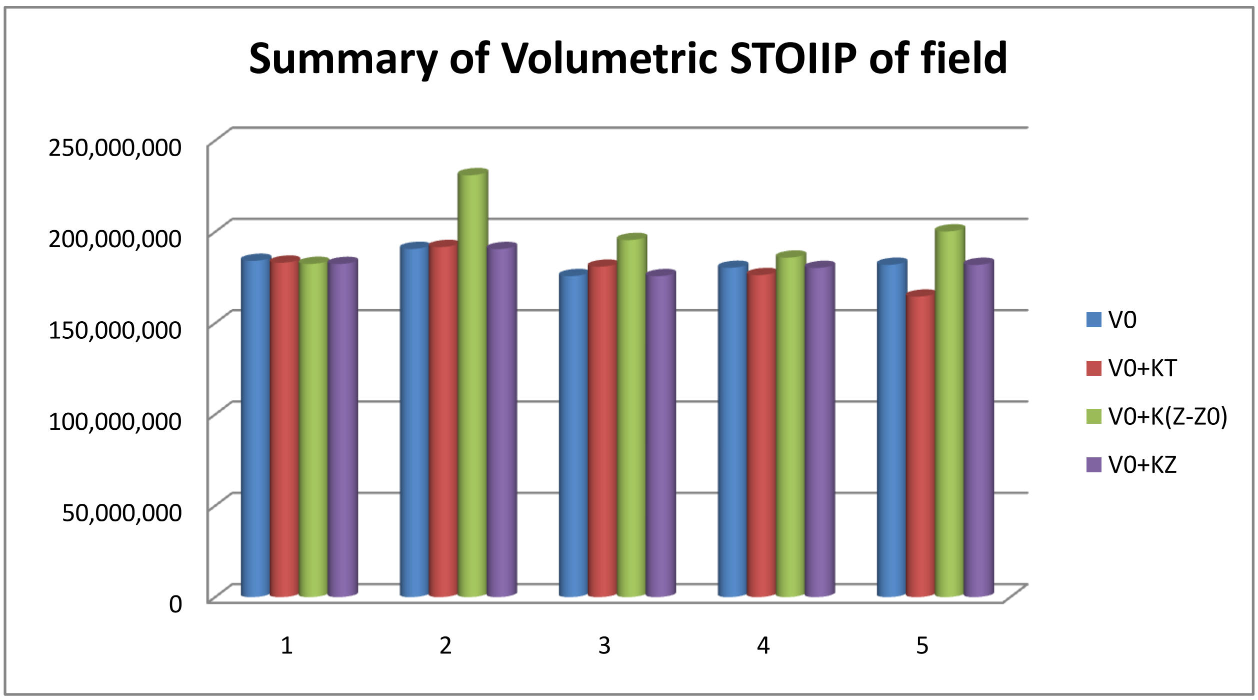

Figure 7: bar graph showing the summarized volumetric STOIIP for field.

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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