INTERPRETATION OF THREE-DIMENSIONAL (3-D) SEISMIC DATA SET OVER AN APPRAISED PROSPECT IN THE NIGER DELTA

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ABSTRACT: Realistic interpretation of three-dimensional (3-D) seismic data set calls for the full integration of the available geological and geophysical skills. The requirement for this full scale integration has necessitated the use of modern interactive workstation that run on powerful machines, and the co-ordination of seemingly unrelated aspect of studies and the pooling of ideas. In this study, the progress of this work was steered along support systems based on specialised packages that are the latest in the industry. The result of the 3-D interpretation has increased subsurface resolution of the prospect that has already been defined on the basis of an earlier 2-D interpretation procedure. Having thus properly defined the structure of interest, contour maps in time and depths were defined for each of the hydrocarbon-bearing (in this case oil) sands that are of commercial interest: the closures on the time maps are pointers to oil accumulation while the annotations on the depth maps give an idea of the approximate distance to the top of sand of interest.

Introduction

The interpretation and analysis of three-dimensional (3-D) seismic dataset, whether for structural or stratigraphy determination has witnessed such tremendous growth in operational procedures that any interpreter worth his salt must keep pace with emerging technologies lest he/she be found lagging behind.

Coffeen (1986) in his book "Seismic Exploration Fundamentals" remarked that for most of the years that seismic exploration has been in existence, seismic interpretation has been done pretty much the old way, with people making pencil marks on sections, reading the reflection times of those marks, plotting the times on maps and contouring the maps all by hand. This procedure would be sufficient for small 2-D dataset acquired over closely spaced grids. A number of interpretation systems that use interactive displays on computer screens have come into use.

Advances in reservoir identification, evaluation and characterisation and the whole concept of field development plan (FDP) objectives are also direct offshoots of advances in 3-D seismic data interpretation. Brown (1988) reported that Tegland was one of the earliest workers in the realm of reservoir identification from their bright and flat spots character. The observation of the amplitude character on seismic sections was made possible because amplitude was preserved in the seismic processing stage. Prior to this time when records were normally made with AGC (Automatic Gain Control), there was little opportunity for studying amplitudes.

Improvements in seismic data processing from the 1970s onward to the 1980s have now made it possible to consider, apart from amplitude and spatial extent, polarity and phase relations in reservoir identification. Frequency, velocity, amplitude/offset and shear wave information can also help greatly in the positive identification of hydrocarbon indicators. Overall pay zones especially gas sands can now be positively identified. One relatively recent method for correctly identifying gas sands was the technique of AVO (Amplitude Variation with Offset) that had been discussed extensively by Backus, Goins and Ostrander (Brown, 1988).

Amoco Production Company, Champlin Petroleum Company and Chevron, USA Incorporated optimised the field development plan for the East Painter Reservoir field in the Wyoming Overthrust Belt in a study reported by Donal G. Johnson (Brown, 1988). Information from the detailed seismic programme using the most sophisticated tools available helped to guide the locations of the last thirteen development wells and all of them were successful. The total turnover from the investment was judged to be satisfactory. This seismic program totally subdued the interest of the first seismic program, which was a 2-D survey; the interpretation of which did not provide a sufficiently reliable picture of the structure of the objective Triassic Nugget horizon to permit an aggressive development programme.

On the whole, emerging technologies and modern acquisition, processing and interpretation techniques properly coordinated in an effective seismic program would result in gains far beyond the expectations of the seismic programmes of a mere couple of decades ago. As demand for the world's total consumption of energy go up, so too are the challenges to the field geophysicists and geologists to integrate their resources more than ever before to meet these challenges.

Luckily the science of geophysics is flexible and dynamic enough to weather very rapid change at short notices:

Objective of this Study

The field of interest in this (simply called Field Arby here) is located in the present Bayelsa State and had been explored previously using the two-dimensional (2-D) survey technique: the field has also been appraised on the basis of (2-D) interpretation. The 2-D programme is contrasted to 3-D exploration in that shooting with reference to shot and receiver points are carried out in closely spaced perpendicular grid lattice-like network, thus ensuring adequate coverage of the target sub-surface structure. Whilst 3-D interpretation procedure is almost impossible without the aid of vast and powerful computer systems, 2-D interpretation can be quite easily followed through manually. The purpose of carrying out another appraisal over Field Arby was recognised from the expected benefits that could be derived from re-shooting this field based on 3-D configuration instead of the previous 2-D configuration that was used and redefining the structure based on the new and powerful 3-D interpretation techniques. A new definition of structural pattern means a review of the initial total volume of hydrocarbon-in-place. Already, in 1990, a well had been drilled (TD=3578 metres) on the strength of the result of the earlier 2-D interpretation. What was then structurally defined as an elongated East-West trending footwall against a major anthithetic fault bounding another field (Field Barth) to the south was tested. The well encountered a total of 92m pay zones in 4 intervals, the D9.0 E1.0 E1.3 and E2.0 sands between 2.5 and 2.7km. By properly integrating the results of the 2-D and 3-D reviews a confident approach to the all-important Field Development Plan (FDP) can now be undertaken.

A powerful impetus for this re-appraisal was the recognition in 1995 after a field review interpretation and reservoir characterisation) of the Field Barth 3-D data carried out by the Exploration Department revealed the eastern nose of the Field Arby structure. Since the Arby and Barth fields lie in the same macro-structure, it reasonably follows that a fresh appraisal of the Arby field was required for a revised estimate of the in-place oil reserves (over the Arby prospect gas accumulation is found in such minuscule amount as to be considered virtually non-existence). In order to fully define the structure, a 2D/3D review was carried out which showed that the Arby field is a large crestally faulted rollover anticline.

This significant change in the structural configuration of the Arby field warranted the revision of the volumetric estimate of reserves (these figures are still classified).

PROCEDURE

Introduction

The areal extent of Field Arby is observed to lie between In-lines 8390 to 8960 and Cross-lines 3470 to 3833, as is seen in the base map of Fig.1.

Before an interactive 3-D interpretation is done, it is standard procedure for horizon of interest to be identified in the seismic tie so that any particular horizon of interest can be followed through in the interpretation stage quite accurately. It is also standard practice that faults are interpreted in the dip directions and then horizon could be interpreted in both the dip and the strike directions, (Jev, 1992, Onabadejo, 1995).

The Arby data that was loaded for this survey was processed using the standard Shell polarity, which is the reverse of the standard SEG (Society of Exploration Geophysicists) convention. The shell convention assumes all positive peaks on the wiggle trace displays to represent sands and all negative peaks to represent shale bodies.

One easily recognisable feature of this dataset as viewed on the seismic sections was the very obvious patches of poor data zones that distorted portions of these sections and which was the result of poor data processing job executed by the contractor.

There are also two standard modes of display of the seismic section that could be shown in the interactive environment. Each of the seismic sections could be displayed either in the wiggle trace mode or the variable density mode (Doust and

Omatsola, 1990). The seismic sections that were used in the course of this interpretation were presented in the colour scheme representative of blue-red-brown combination in which the blue streaks are sands bodies and the non-blue streaks are non-sand bodies.

Fig.2 shows the seismic section for dip line 8918 that has been presented according to the format just described above, while Fig.3 shows the section for dip line 8710. In both cases the areas of poor data control are visible. Fig.4 is the strike section of crossline 3570: strike lines are perpendicular to dip lines and faulting are not very clearly defined along these strike lines.

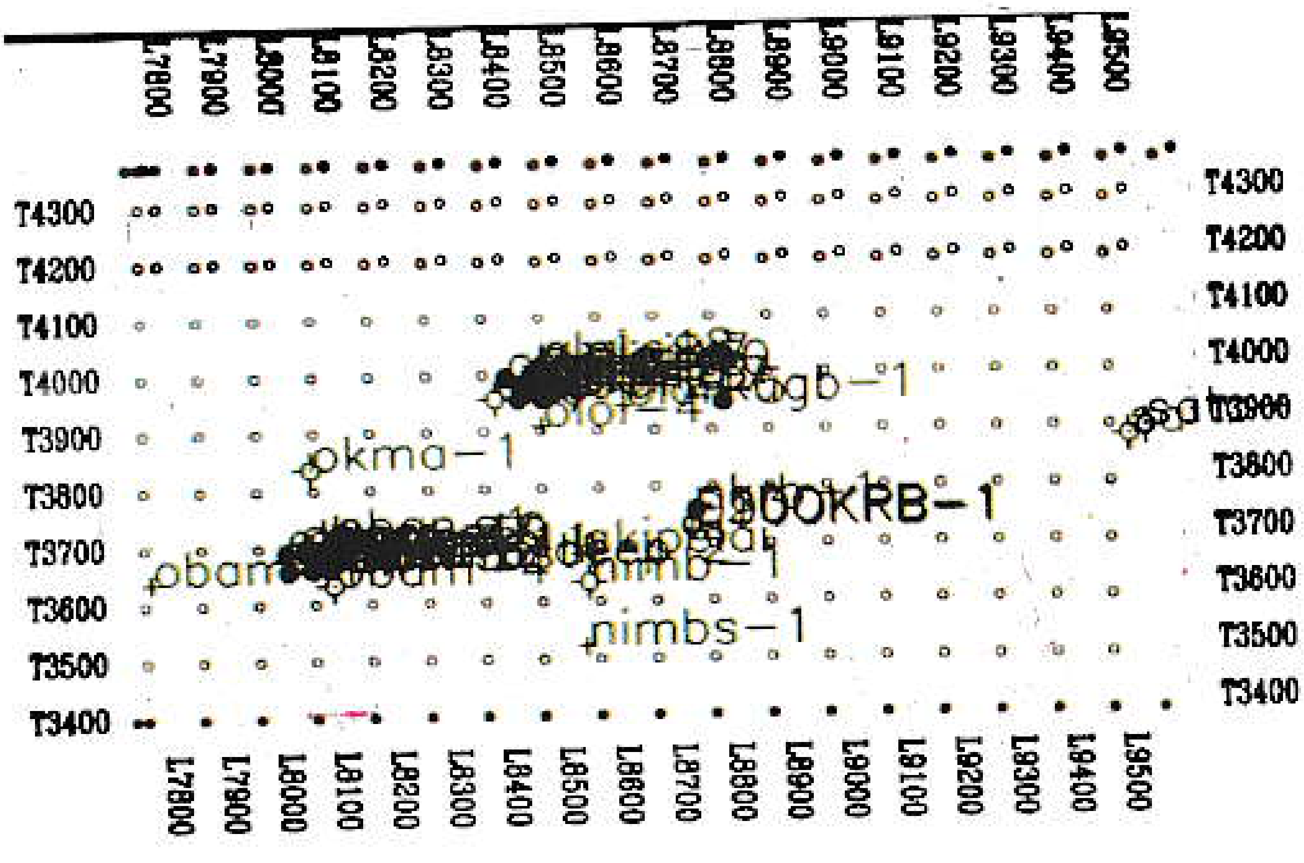

Fig. 1: Basemap Showing Area of Field Arby

The most obvious feature of this interpretation exercise was the total elimination of paper sections on which fault and horizon interpretations were usually done. Instead interpretation was carried out on computer screen that display seismic sections in either the dip or strike direction one seismic line at a time. The interactive workstation consists of a double computer screen and the central database hard drive where all the 3-D seismic projects for different surveys are stored. One of the screens usually displays the basemap of the area of the seismic survey while the other screen display the seismic section across a particular dip line or strike that was chosen on the basemap.

Well-to-Seismic Match for Horizon Calibration

On the surface of it well-to-seismic matching (WSM) technique is simply a tool to aid correlation of well data calibrated in depth and seismic data calibrated in time (Overell and Heer, 1994). It does certainly involve building up synthetic seismic sections. Very often and essentially so, it is necessary to be able to put a definite signature on the lithology type of pronounced reflection observed on a seismic section. One should be able to say with certainty "this reflection represents so-and-so unit" and so on. The geographical extent and the position co-ordinates of any reflection event on the seismic section can be determined with near-accuracy.

For any seismic section with pronounced reflection of interest, with the position coordinates determined a well can be drilled in the location of interest and from this well different formations (or geological layers) are determined and calibrated in depth. The question now arises as to which layer or layers encountered in the well correspond to the pronounced reflection(s) on the seismic section. How this sort of correlation or matching is done constitute the essential framework of the well-to-seismic technique.

The essential requirement for the matching procedure is the creating of synthetic seismograms (synthetics) from data obtained at the well site. Well log data, especially sonic and density logs are employed in the making of these synthetic seismic sections. These pseudo-seismic sections with adequate well (depth) control are then juxtaposed with the real seismic sections of interest and events on the real sections are then calibrated with acceptable precision.

The matching procedure for this exercise was supported on machine based on the Schlumberger's GeoQuest's Z-compose environment (Van Luik and Ekejiuba, 1996). The synthetic seismic section created from the sole well of the Arby prospect (Arby-1) by the Special Studies Team at SPDC-East was made available for this project exercise. The "refined" version of the synthetic was then exported into the Z-compose environment along with the seismic section on which the Arby-1 well was visible. Matching was executed by juxtapose of the synthetic and seismic section, beginning initially at zero time shift but did not produce a satisfactory match and the seismic section was then slid just upway relative to the synthetic section until a satisfactory match was obtained at a time shift of about 20ms.

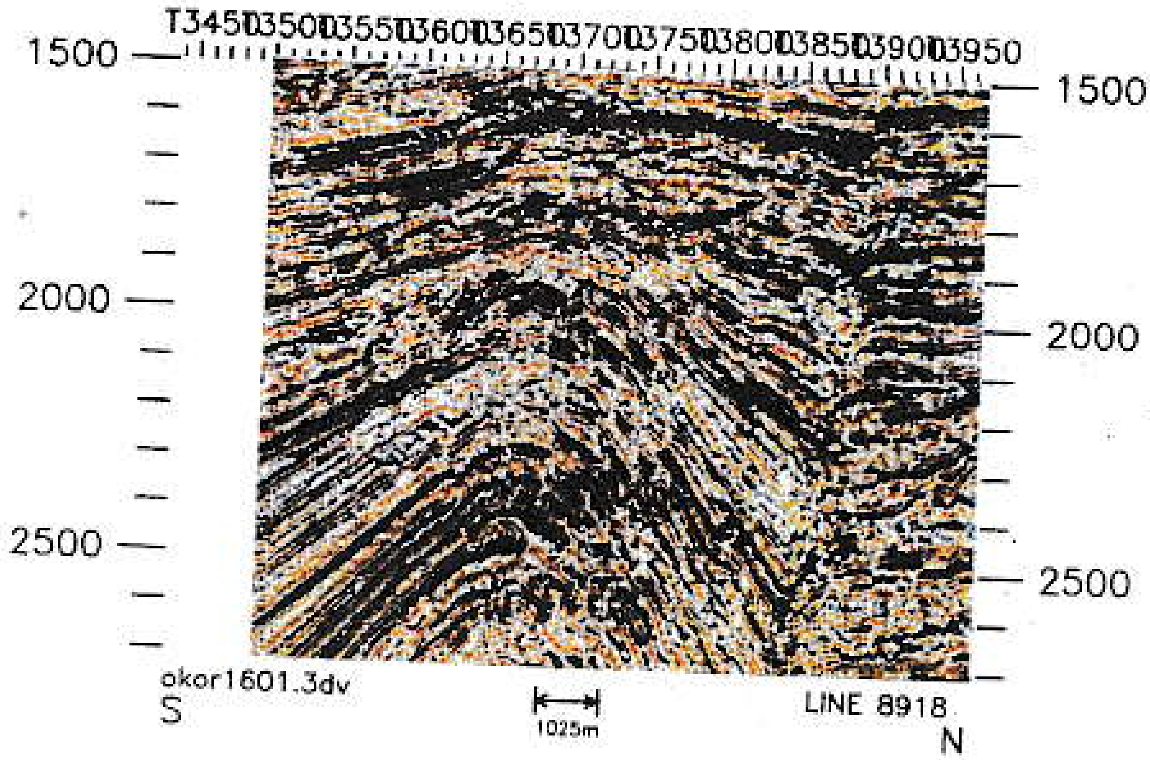

Fig. 2: Dip Line 8918.

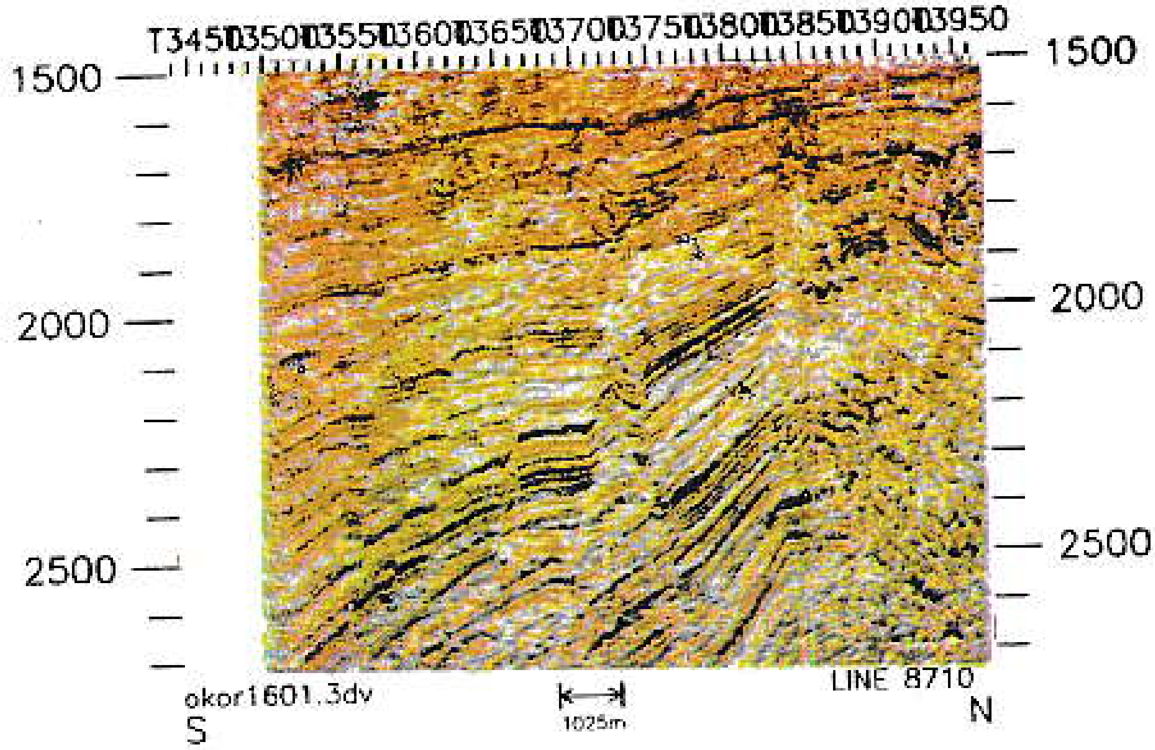

Fig. 3: Dip Line 8710

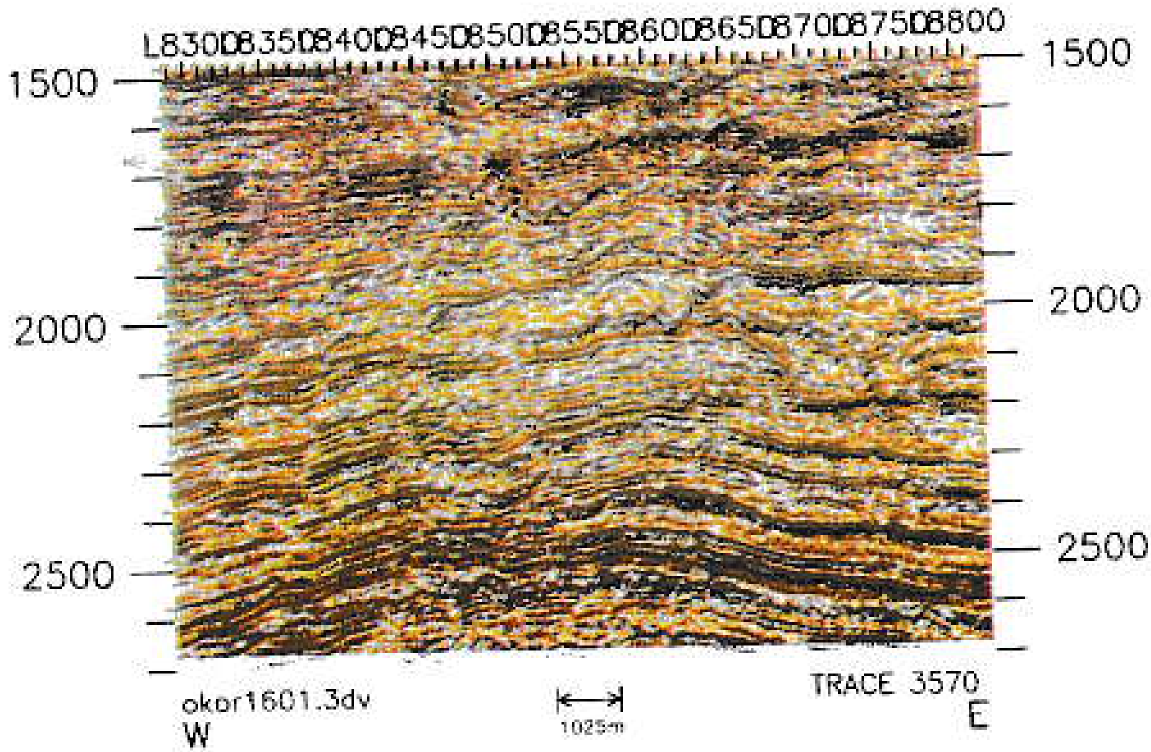

Fig. 4: Strike Line 3570

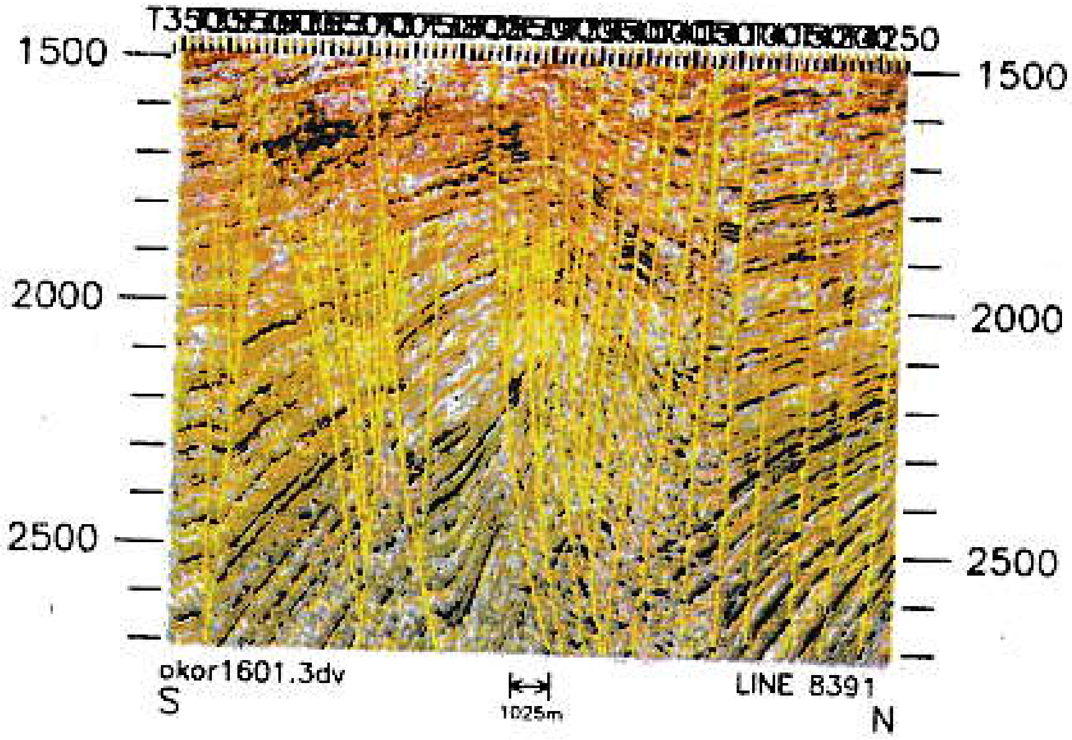

Fig. 5: Interpreted Dip Line 8391.

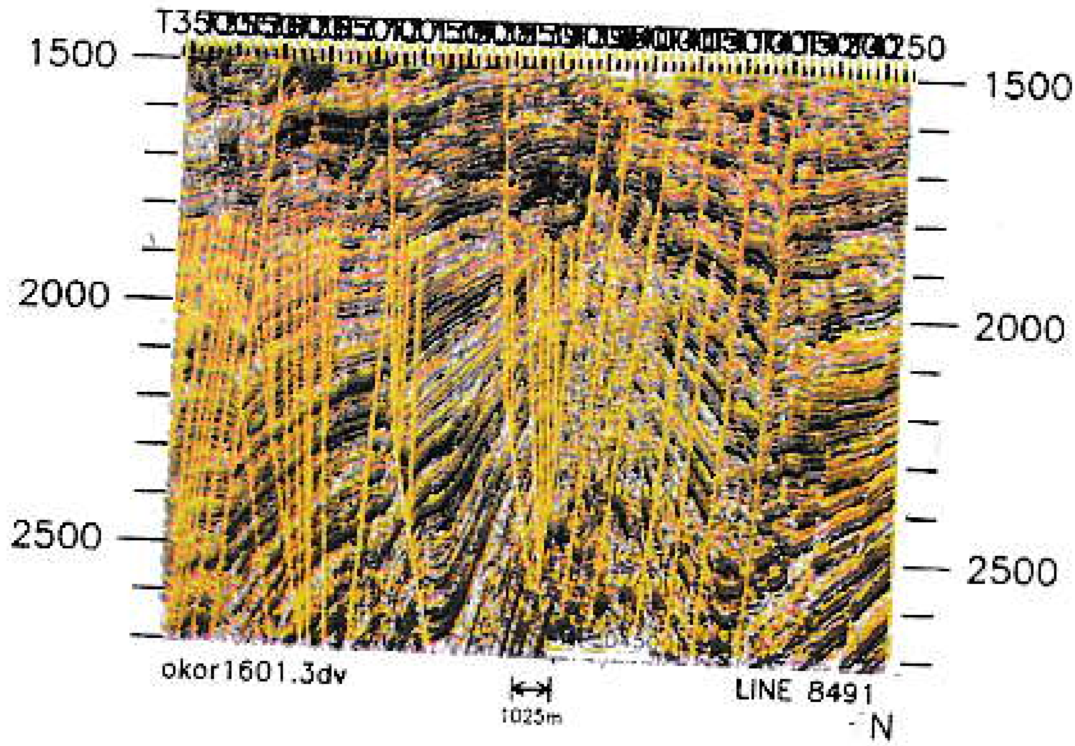

Fig. 6: Interpreted Dip Line 8491.

The Arby-1 well has better petrophysical control and the conclusion drawn from the result of the log run done in the well indicated that four major oil sands were encountered by this well, the D9.0, E1.0, E1.3 and E2.0. The first attempt at the well-to-seismic matching technique was to properly identify the D9.0 sand on the seismic section (in the dip direction, that is).

Fault Tracking and Interpretation: Arby Field

Each dip line was interpreted on the basis of the faulting trends that were easily picked and the horizon of interest that can be followed through. Interpreting each strike and dip line for increment value of 1 frame each for the extent of the survey would be extremely cumbersome and time consuming and thus it was decided from the start that interpretation would be done for incremental values of 8 frames and then the autotracking procedure would be invoked when the computer would then automatically follow the interpretation for those frames that were not manually interpreted in the basis of the interpretation that was already done.

This interpretation exercise was carried through bearing in mind that a fault seen on any seismic section represented break in the continuity of the horizon. The fault tracking and interpretation exercise was carried interactive on the Landmark support system currently installed at the SPDC-East (Port-Harcourt). The session began from the Openworks 4.1 Command Menu and then the Seisworks 3.4.

To track and interpret these faults, a reconnaissance of the seismic sections was done to determine fault trends, which is a sort of visual control procedure. The next important step was the picking of major faults on network of lines and then picking secondary faults after these (see figs 5, 6 and 7). It is seen from these figures representing dip lines 8391, 8491 and 8591 respectively that a major fault, which is the Arby boundary fault, hades north and cuts through a large extent of the seismic section. That is also an antithetic fault. This fault is very prominent and can be traced out on almost all of the seismic sections for the extent of this survey. Another major fault, though less prominent than the antithetic can be seen on this seismic sections to be hading in the south direction and this is known as a synthetic fault. The seismic sections also show faults (minor faults) hading due south in opposite direction to the major boundary faults; these are also synthetic faults and they have been picked (interpreted) and marked out in the yellow annotation colour which is conventional for the Seisworks 3.4 environment.

One obvious feature of this faults interpretation exercise was the interactive nature of the task of picking fault segments on each of the seismic sections displayed in the seismic view window so that interpreting the dip lines between 8390 and 8960 at incremental values of 8 frames resulted in the successive interpretation of at least 72 dip seismic sections for this Arby exercise that must be carried through quite accurately. Wrongly picking, omitting or wrongly assigning fault segments would distort the final result of the interpretation.

As can be observed in Figs 5 through 7, complex faulting patterns in the Arby prospect area has resulted in complex structural configuration of the interbedding sands and shale bodies so that as is the case in the Niger Delta the subsurface geology is characterized by extensive fault traps. Fault interpretation was completed on 72 separate seismic sections in the dip direction while the progress of the exercise was continually being updated in the central computer system.

Correlating Fault Segments

When fault interpretation was complete, the fault segments were assigned to fault plane (i.e a geophysical model of the fault in space) by assigning individual segments to a fault and this was done in the Map View window of the SeisWorks environment by selecting the major antithetic fault that is seen to be hading south was assigned to the synth1 fault plane (pink colour). Continuing in the direction the various faulting trends discernible on the Map View window after calculating heaves were assigned to different planes depending on whether these were synthetics or antithetic synth2 (dark red colour), synth3 (yellow colour), synth 4 (blue colour), and so on.

The fault heaves that were computed in the region of the interpretation and displayed in the Map View window always would trace out the outline of fault segments on very close examination across the region of the seismic section where there was a better data control. This fault outline was then systematically followed by checking on the individual component of the faults heaves using the computer mouse and further assigning all the heave components that formed the outline of a particular fault segment to a common colour (i.e correlating).

Before fault segments were correlated, the horizon of interest was interpreted through markers indicating fault planes on the seismic sections, bearing in mind that on these sections any fault plane represented a break in the continuity of any horizon that it cuts through. The horizon of interest was never picked in one continuous whole through the fault plane markers on the seismic sections but in a series of disjointed lines always terminating at the point it meets a fault plane marker. The break through the fault plane trace is a measure of the heave of that fault cutting through the horizon: the heave of a fault is the horizontal component of the separation of any horizon unit.

The fault heaves were calculated by invoking the computers' "slash command" when in the horizon interpretation mode of the SeisWorks environment. On the Map View the computed heaves traced out fault segment patterns or shapes that were then correlated as singular fault segments defining polygons of various shapes and sizes that are proportional to the actual shapes and sizes of the faults occuring in the subsurface.

On the Map View window of the interactive display, a fault heave is always shown as a tick pointing in either the upward or downward direction depending on whether the tick is representative of either the upthrown part of the fault concerned. The throw of a fault is the vertical component of the separation of a rock (horizon) unit.

Drawing Fault Polygons

After assigning fault segments in the course of this interpretation, fault polygons that appeared on the Map View were edited in order to allow for a smoother fault trend as seen in Fig.8.

Fig.8 reveals the fault structural pattern of the D9.0 sand over the Arby prospect based on interpreting the 3-D seismic data set of the field between dip lines 8390 and 8960 and between strike lines 3470 and 3830. The major fault trace observed on the dip seismic sections as the boundary fault is easily followed on the map view as the most prominent fault segment. Other fault traces observed on the dip sections that were interpreted have been drawn out also in this figure. The essential difference between this result and the resulting structural pattern based on the earlier 2-D interpretation is the resolution of the very small fault details that could not be resolved by the 2-D data and on the observation of apparent fault closures around the crest of structure. The observation that the major boundary fault observed on the north end of the Arby prospect is bounded just on its south side by two fault segments closing in an arch shape is the finest detail point that the result of the interpretation of the 3-D seismic data was able to elucidate that the earlier 2-D interpretation could not. This observation has very important implications for field development plans because it has eliminated by a great margin the probable error associated with the location of new exploratory wells. This deduction is apt because it is a geological fact that the Niger Delta which is characterised by extensive fault traps, boundary faults and fault closures are often associated with hydrocarbon accumulations.

HORIZON INTERPRETATION AND TIME MAP

Introduction

The conventional seismic sections along strike and dip directions are seen to comprise of alternating stacks of sand and shale beds below the surface. As pointed out earlier on, the processing convention and colour scheme used for this seismic data show the blue streaks to represent sands and the red streaks to represent non-sands. Each of these layers is usually called a "horizon" although the term has been most commonly associated with sand beds.

The practical value of the well-to-seismic matching technique was put to use when the identified horizons of interest (i.e the D9, E1, E1.3 and E2 sands) were interpreted in both the strike and dip directions: in the strike direction between inlines 3470 and 3830 and in the dip direction between cross-lines 8390 and 8960 at incremental and decremental values of 8 frames.

Fig.9 is the seismic section of dip line 8590 showing the D9.0 horizon that was interpreted through the fault traces. The D9.0 sand seen here was picked from around 2500ms and continuing upward with a crest at around 2100ms while the horizon could not be accurately followed in the zone of poor data seen on the north side of the seismic section.

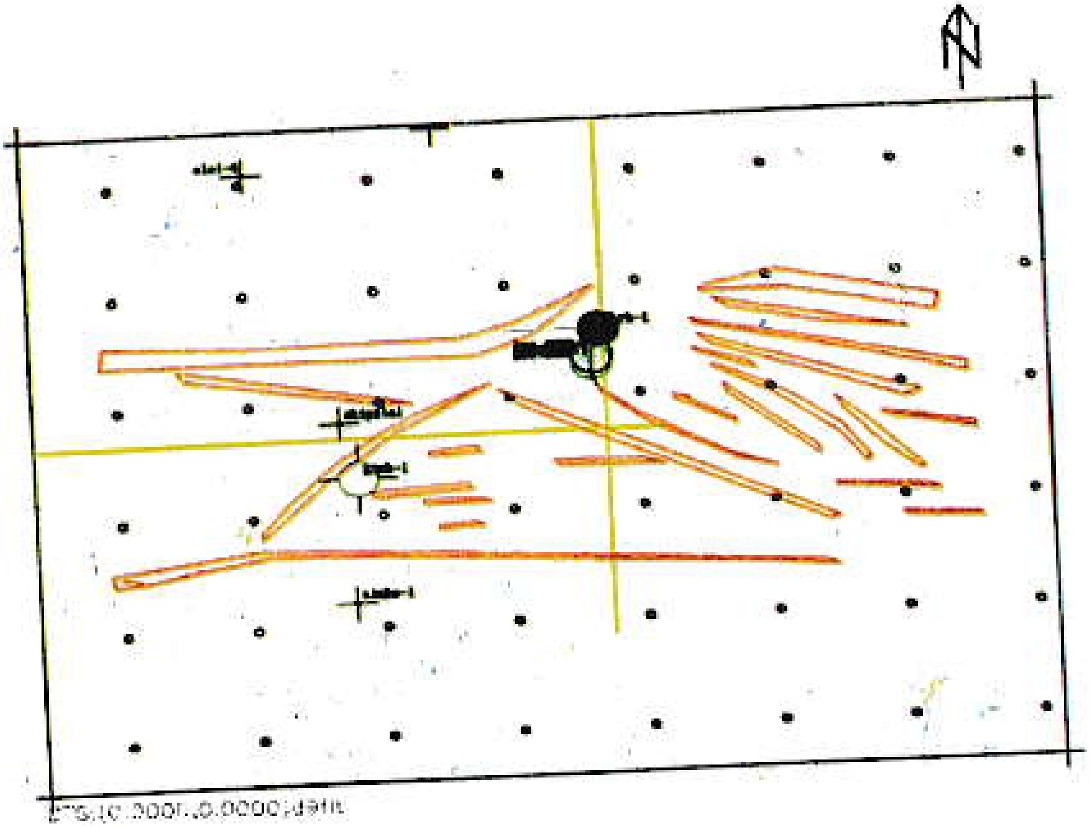

Fig. 8: Field Arby Structural Pattern

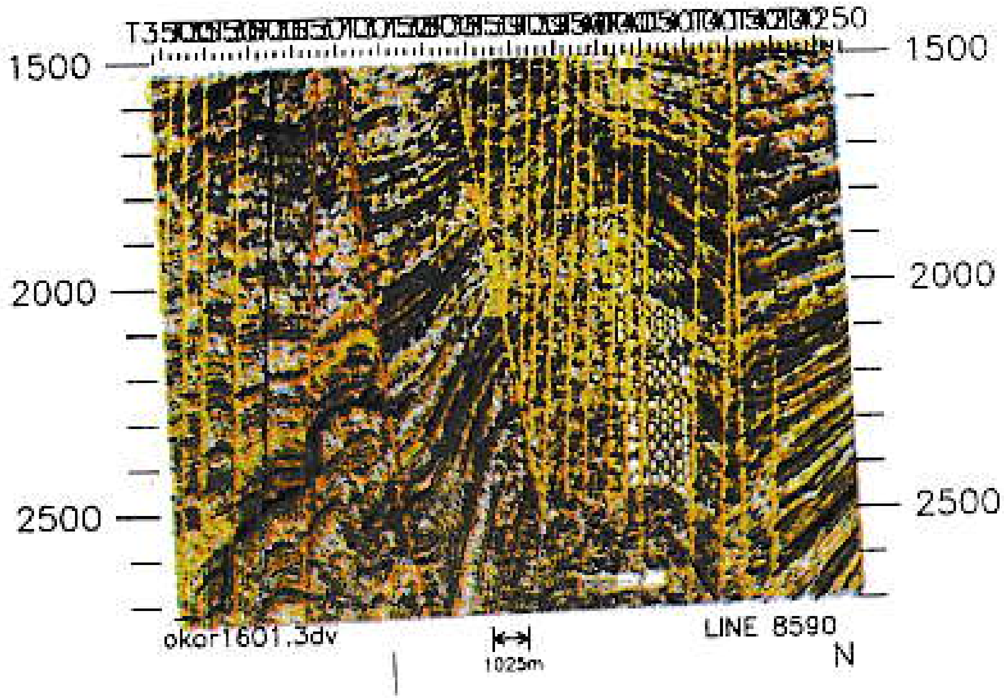

Fig. 9: Interpreted D9 Horizon on Dip Line 8590

Fig.10 is the dip section for line 8782 showing the result of the horizon interpretation that was carried through.

The well-to-seismic match was originally done on a seismic section in the in-line direction and the horizons were followed through quite easily in areas of good data control while great care was taken to pick this horizon along areas of poor data and heavy faulting which are both common feature of the Arby dataset.

In order that the horizon sands are properly identified in the strike direction a system function called horizon intersection circle was enabled in the interactive environment. By this means the various sands were identified in the strike direction by circles in yellow annotation colour appearing along the extent of the sand.

The horizon intersection circles served as guides to correctly interpreting the separate horizons in the trace direction.

The four horizons were interpreted on 72 different seismic sections along the dip direction and on 45 different seismic sections along the strike directions of the dataset. Since the interpretation was interactive and involved absolutely no paper sections at all, the progress of the interpretation was continually being updated in the central database of the computer system.

ZAPPING! The Horizons

Since horizon interpretation was done on frames for incremental and decremental value of 8 frames depending on the initial reference frame, it became necessary to decide on how those frames (i.e seismic sections) that were skipped by the interpreter should be incorporated into the interpretation process. The ZAP! function was invoked to autotrack the 316 (i.e 360 - 45) different seismic sections along the strike direction on which the different horizons were not

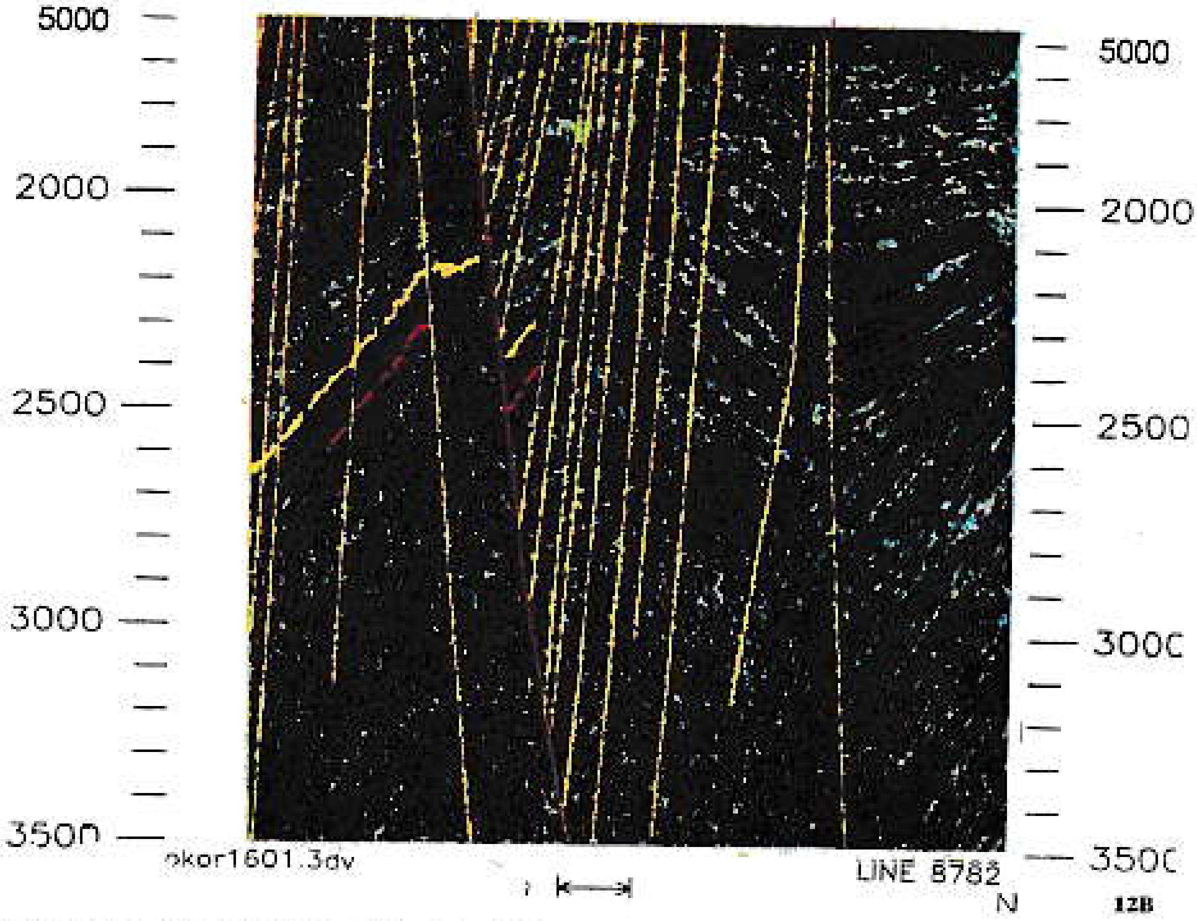

Fig. 10: Horizon Interpretation on Dip Line 8782.

manually tracked (or interpreted) in order to achieve complete coverage. Before the ZAP! function was invoked the interpreted horizons over the Arby prospect in both strike and dip directions in the seismic sections that were manually tracked was updated in the Map View window in a grid format.

Post-Zap! Restoration

When a ZAP! function is first run there are often patches of "gaps" or "black holes" in the zapped area extent appearing on the Map View window. These are often areas that were certainly not autocracked and results from poor data control that hinders perfect interpretation of faults or horizons on the vertical seismic sections. It is often better to interpolate or fill these patches after ZAP! is run. There are two approaches to the restoration procedure at the moment in SPDC-E: the second is the restoration procedure supported on SPIRIT/TIS (a Shell in-house application that can run on the Open Works platform), both procedures ultimately, achieve the same objective. For this Arby project exercise, filling up these patches were first executed on the SeisWorks platform on trial basis but a more involved restoration procedure was done in the SPIRIT/TIS environment.

Amplitude Analysis

Amplitude extraction for the different horizons was carried out in the course of this interpretation exercise. Usually, this process is associated with the ZAP! function when this is run on the SeisWorks platform. Alternatively, amplitudes are extracted in the SPIRIT/TIS environment and this is the standard procedure employed in the extraction for amplitudes in the course of the work. Amplitude analysis is usually done to facilitate the recognition of the DHIs (Direct Hydrocarbon Indicators) and the result is presented on a map showing regions with bright spots properties (important indicators of hydrocarbon) contrasted to non-pay zones. Of the four sands that are of interest in this exercise, DHI is more prominent for the E1.3 sand.

Mapping Horizon in Time (CPS-3)

The interpreted time map for any horizon can be contoured in a mapping environment. These contours are usually time contours defining variations of arrival times across the interpreted structure and most times the interpreter studies regions of closures on the map intimately. The interpreted horizon is of course displayed in either the seed grid format or the ZAPPED format. After the horizons of interest were manually interpreted on a total of 117 seismic sections (72 dip sections and 45 strike sections), autocracked to give complete coverage, fault heaves calculated, fault segments identified and assigned, fault polygons drawn, the horizons file was then exported from the Landmark environment into the CPS-3 environment where a time structure map was made for this horizon. The time structure map show the variations of arrival times over the D9, E1, E3 and E2 structure.

Examination of the time contour maps of the D9, E1, E3 and E2.0 sands drawn at intervals of 10ms and presented on a map scale of 1:50000 reveals that the region around where there

is a fault closure and just to the south side of the major boundary fault is characterised by relatively low times compared to the southern and extreme north-eastern flank of the structure. Lower time values correspond to relatively shallower regions of the various sand bodies with respect to the region of the structure that are characterised by higher time values. It goes without doubt, therefore, that the area around the crest of each of the sands is the area around the fault closure to the south side of the boundary fault. In each of these figures, areas for which data control was poor in the original seismic sections are reflected as "bull eyes" in the time map where thick contour clusters are noticeable. These time contour maps for each of the sand is seen to define anticlines in structural orientation with the shallower portion corresponding to the crest or arch of the anticlinal form.

Discussion of Result

This structural configuration is presented in plan view mode (as seen in Fig.8). Each of the series of synthetic and antithetic fault trends that were interpreted on the seismic sections was correlated as individual fault segments on the Map View window after the calculation of heaves.

It has been recognised even from the result of the previous 2-D interpretation that the Arby major structure bounding fault is an acute drown-to-earth basin fault which also encompasses the Check, Daryl and Arby structures and that such faults occur throughout the Niger Delta and are well developed in the Coastal Swamp depobelt. The result of the 3-D interpretation also revealed the presence of this boundary fault in addition to other smaller fault configuration that were not revealed by the 2-D interpretation.

The resulting 3-D structure shows increased fault details over a large lateral extent that contrasts significantly from the structure defined by the 2-D interpretation. These fault details and the increased resolution of the extent of the structure has impacted significantly on the overall total of the hydrocarbon estimates initially in place. The new volumetric estimation has very important implication for the field development plan initiative currently underway (owing to information security these figures are still kept in confidence). In this respect, management decisions regarding the area of the structure to site new development wells can now be based on very sound geological judgement which in the short and long runs would result in significant cost savings.

As fossil fuels resource depletes in effective total recoverable amounts, so the search for them is carried ever deeper into the ground and the need for sound and correct judgement is ever more important. The risks involved in drilling dry holes increase in proportion to the complexity of the enabling geological environment suitable for hydrocarbon generation, migration and trapping. Most of these risk factors that translates into very high cost are better managed by employing advances in modern earth science technology. Depending on worldwide consumption pattern of fuels, which obviously influences the demand and supply equation pressures are borne down on the professionals involved in the search and processing of fuels and their products. Over the decades, however, the world has witnessed quite rapid rise in population and the consequent rise in the demand for energy and thus on the whole, the expectations on the field geologists and geophysics have been on the very high side.

It appears that on the whole there is hardly a science (perharps Information Technology, just so) that has been so inundated with change in so short time spans as the science of the earth and it is well known to everyone involved in this field that the strongest onus lies with the seismic data interpreter whose final recommendation determines the success of any particular drilling campaign or not. In this respect the task of the seismic data interpreter becomes a highly skilled affair demanding flexibility and adaptations to changes.

The time contour map and amplitude analysis carried out over the 3-D structure is refinement to the overall interpretation procedures. Amplitude maps show direct hydrocarbon indicator (DHI) attributes whereas time map show variations of arrival travel times across the structure. Contour closures are observed on the time map at regions corresponding to locally bright spots on the amplitude map, therefore corroborating the well-known fact that time contour closures are characteristic of hydrocarbon accumulations.

Conclusion

The major boundary fault obviously is a very good barrier to hydrocarbon migration path. Closures around this fault are defined by the series of synthetic and antithetic faults here. With better resolution showing fault closures in detail, hydrocarbon migration down flank is now thought to be limited to just leaks and spills across faults thus redefining the total hydrocarbon volumetric estimates for this prospect.

It is obvious already that downflank structure is most unlikely zone to drill any well at all and it is most strongly recommended to concentrate on the crest around the region of fault closure. The sole Arby-1 well has already been drilled upflank, but now with better idea of the nature of the structural pattern over this prospect, the next drilling campaign can be carried through with minimal economic risks short of guesswork. Without this 3-D structural control, programme judgement would have been heavily based on blind guesses.

The singular most important benefit of this interpretation exercise is the presentation of the new geological pictures of the Arby prospect, which is backed up with the certain positive conviction that recommending to management to drill more appraisal wells on the crestal of the structure has very slim chances of turning out dry.

The area on the crest of the structure to the west of the Arby-1 well should be considered thoroughly in the well planning stages of this field development programme as the result of the amplitude and time map would corroborate. This exercise has delineated the extent of the Arby prospect more properly than before and the next phase of the field development could now commence.

It is strongly recommended that, as a matter of policy, all old 3-D seismic data should be revisited at about five years intervals as more data become available and new technologies emerge. It is hoped that this will help discover the latent potentials of any field. With time, it will be beneficial for the company to embark upon re-shooting of 3-D seismic with a view to providing the fourth dimension (time) in the database i.e 4-D. Areas of bypassed oil and sub-optimal production performance and policy can thus be highlighted.

Acknowledgement

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References

Brown, A.R., (1988). Interpretation of Three-Dimensional Seismic Data, 2ed: American Association of Petroleum Geologists (AAPG), Tulsa (Oklahoma), pp.1, 6-7, 183-192.

Coffeen, J.A., (1986). Seismic Exploration Fundamental, 2nd ed, PenWell, Books, Tulsa, Oklahoma, pp.220.

Doust, H. and E. Omatsola: 'Niger Delta' in "Divergent/Passive Margin Basins". ed. J.D. Edwards and P.A. Santogrossi: A.A.P.G. Memoir, 48 pp.201-238

Jev, B.I. (1992). "Seismic Interpretation Report of the Ekulama 3-D Seismic Survey", SPDC, Port-Harcourt.

Onabadejo, O.A. (1996). Re-interpretation of Ekulama 3-D Field Seismic Report, SPDC Port-Harcourt.

Overell, J.S.W. and P.E Heer, (1994). Interpretation of 3-D Seismic Data over the Olo-MinNta field SPDC Port-Harcourt.

Van Laik K.W. and A.O.M Ekejuba, (1996). Santa Barbara 3-D Seismic interpretation Report Part II: Special Seismic Studies SPDC.