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TWO-DIMENSIONAL (2-D) SEISMIC DATA INTERPRETATION OF THE IGBOKODA FIELD

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ABSTRACT

Interpretation of the two-dimensional (2-D) seismic survey of the Igbokoda field was carried out on eighteen (18) seismic lines (9 dip and 9 strike sections). The interpretation was done manually to generate a depth structure map, which involves the use of a time strip and the conversion of the time from the check shot survey to depth (in feet). Two main horizons were carried through, timed-looped, and tied to obtain the look of the subsurface.

INTRODUCTION

Two-dimensional (2-D) seismic survey and interpretation was the dominant configuration mode in the exploration and exploitation environments before the advent of full-scale 3-D seismic survey and interpretation. Jonah (2000), quoting Coffeen (1986) pointed out that 2-D seismic surveys were conducted along a series of (usually) straight lines, as contrasted to 3-D seismic surveys that were conducted along densely-packed (closely-spaced) grids and bins. He further remarked that in the decades preceding the advent of interactive interpretation supported on powerful graphics-based machines, the interpretation of 2-D seismic dataset was done much in the conventional manner, with people making pencil marks on sections, reading the reflection times of these marks, plotting the times on maps, and contouring the maps all by hand. This procedure was sufficient for small 2-D dataset but was extremely tasking for a regular 3-D dataset and near impossible for a large 3-D dataset. The 2-D seismic section is, in reality, a cross-section of the 3-D seismic wavefield. It contains signals coming from all directions, including out of the plane of the profile, although the latter is usually assumed to be part of the signals that come from the plane of the profile itself. Although out-of-plane reflections are often recognizable by the experienced seismic interpreter, a well-known problem is that of out-of-plane signals that give rise to misties of 2-D migrated sections from a survey. In a grided survey, problem of mistie can arise if results of measurements along any two given profiles (or grid lines) do not tally at point of intersection of the profiles. The interpretation of 2-D seismic dataset is the bedrock upon which the interactive 3-D workstation is built. Whereas for a 3-D seismic dataset interpretation exercise, large amount of data

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are involved, in dealing with 2-D interpretation the amount of data involved is, in a true sense scaled down. Ultimately, the interpreter hopes to achieve a faithful representation of the subsurface geological characteristics under investigation. Much handling of large seismic paper sections was involved in this Igbokoda study and a rather satisfactory representation of the subsurface geology was produced.

LOCATION OF THE STUDY AREA

Igbokoda field in the south-eastern Niger Delta is located about 30km offshore in the Mobil block as shown in Fig. 1 This field is in a water depth of 88 feet (27m).

GEOLOGY OF NIGER DELTA

A delta is a river fed deposition system that produces an irregular progradation of the shoreline. The entire, sub-aerial and sub-aqueous, contiguous sediment mass is included in the Delta system. The sediments are partly marine and partly fluvial in origin. The Niger Delta basin is the most prospective of the six major basins that are of interest to hydrocarbon prospectors in Nigeria. The other basins are the Bida, Borno-Chad, Anambra, Sokoto and Dahomey / Benin basins. These six basins in all occupies about 178,000 sq. miles, roughly half the onshore of Nigeria. The onshore portion of Niger Delta complex is occupying about 30,000sq miles and offshore portion covers about 70,000sq miles. The entire Niger Delta complex covers approximately 100,000sq miles (Chukwu, 1991). This Delta complex consists of formations deposited in a high-energy deltaic environment. The structural evolution of the Igbokoda field structure is probably related to the regional development of the Niger Delta growth fault pattern. The major growth fault in the area together with their antithetic subordinates appear to have resulted from the plastic deformation of the over pressured and under compacted Akata shale under the weight of sedimentary overburden. Figure 2 illustrates the stages of the growth fault (Opara, 1981). The overburden squeeze Akata in stage 2 and it squeezes out in front as the Delta prograde. The Benin formation is not affected by the growth fault. Mainly, the faulting is prolific in Agbada formation with the growth structure formed in anticline during the process of sedimentation (Weber and Daukoru, 1975). The Niger Delta fault system is characterized by growth fault and rollover anticlines. The fault systems are N-S dipping, in orientation with growth fault being active during the process of sedimentation. It is observed that beds get thicker on downthrown side due to greater subsidence rate and decrease in thickness on the upthrown side leading to rollover anticline. Figure 3 shows the crest shifting with depth (Short and Stauble, 1967). The fault is left inclined and bends horizontal at the base. However, the origin of the growth fault has been subjected to a lot of suggestion by different texts (Short and Stauble,1970).

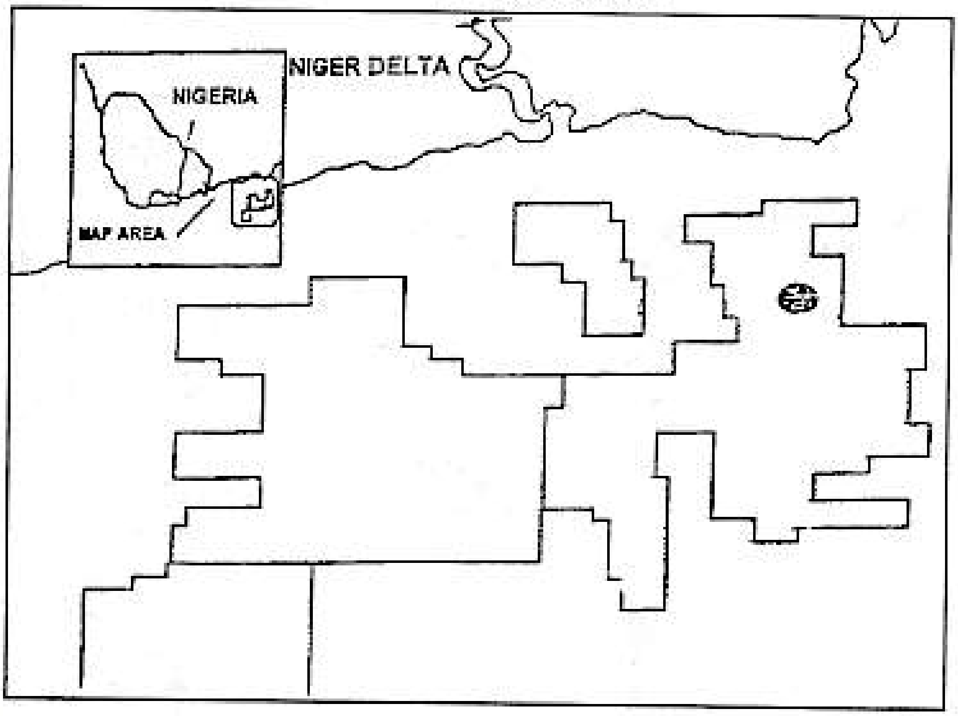


Fig. 1: Study Area

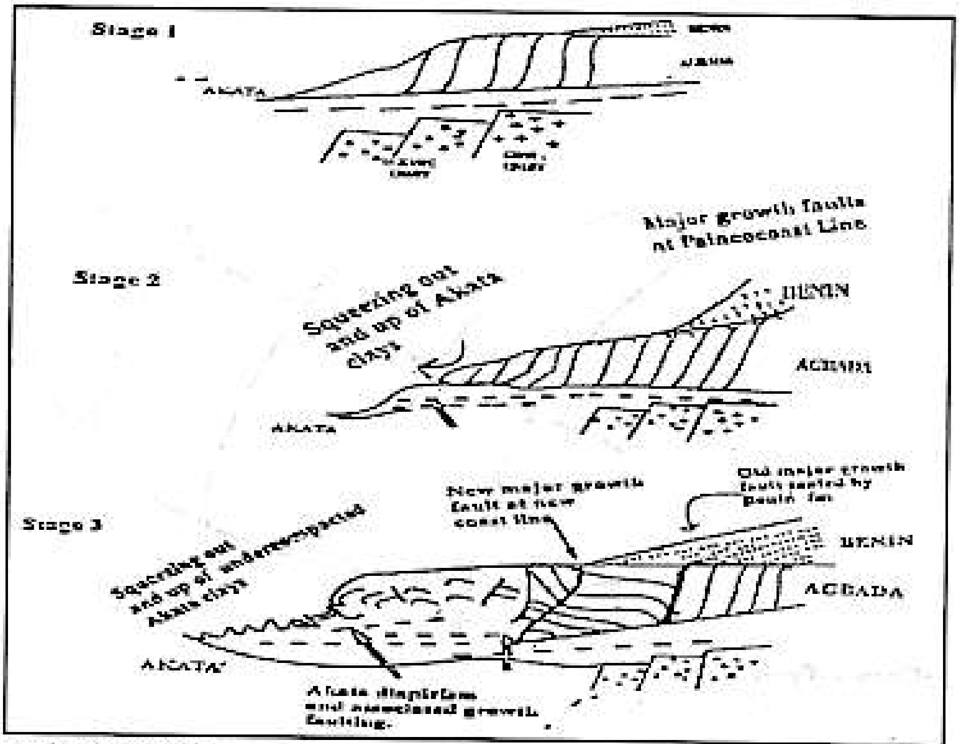


Fig. 2: Growth of the Delta

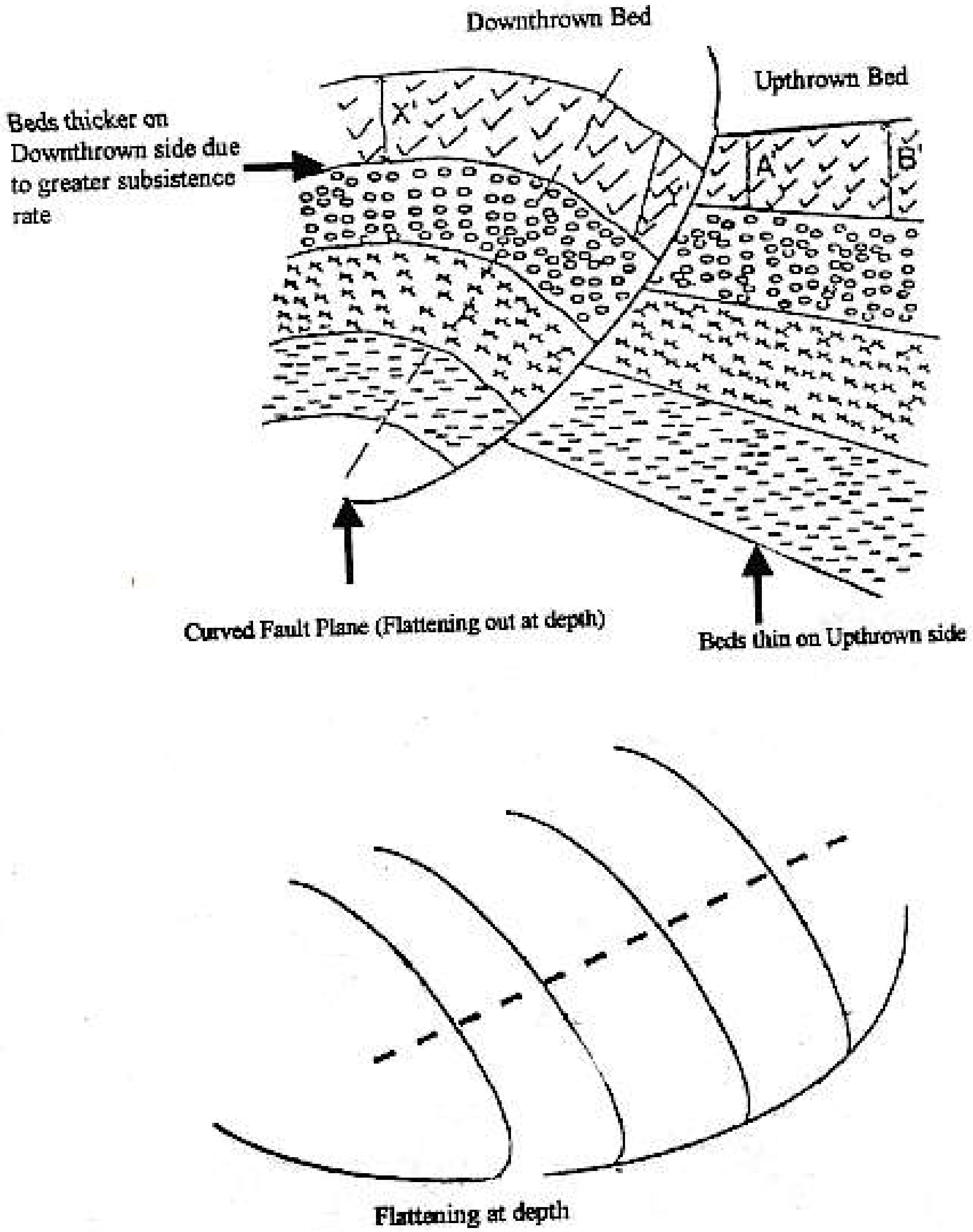


Fig. 3: Growth Fault

INTERPRETATION OF IGBOKODA FIELD DATA

The procedures adopted for this interpretation exercise are discussed in this section. Seismic data recorded on Igbokoda field were provided by Mobil Producing Unlimited Lagos.

Seismic Data Generation

Airgun-based seismic survey was used for the generation of seismic data and this was used to establish the relationship between the seismic data (in time) and well data (in depth). The geological section was assumed to multi-layered earth, with petrophysical parameters fairly constant along the horizontal direction but vary vertically downward.

Step- By- Step Process of Interpretation

In illustrating the procedure for making subsurface maps using seismic data, a defined process of work plan was followed (Fig. 4). This process was further broken into a step sequence showing detailed steps involved in every stage of the reflection seismic data interpretation. Though it is laborious, it was essential for a final well-prepared map generation and prospect analysis.

Identifying Structures to be Interpreted

Two horizons of interest (both oil-bearing) called Blue and Green were identified for interpretation. The identification was aided by the process of well-to-seismic matching in which data that were gotten from a drilled borehole (or well) were juxtaposed with corresponding seismic time sections. Normally oil-bearing horizons are easily identified by the process of drilling a well with the depth of occurrence of these horizons easily determined. These identified horizons and their depths are matched with the seismic time sections. These horizons were found to lie between a two way travel time values of 1.35s (4000ft) and 1.84s (6078ft) on the 2-D seismic sections provided. These two sands (horizons) were recognized based on the correlation of the seismic section with the well log data.

Picking of Faults

On the section of interest the faults appeared as breaks in the reflection continuity of a set of seismic wiggles. Features that are usually indicative of faulting on seismic sections include breaking of events, bifurcation, offset of reflection pattern or change in reflection pattern (change in dip angle) (Elliot, 1972). To trace and interpret these fault sections, a survey of the seismic section was done to determine the fault trends. A quick reconnaissance of this seismic section revealed at a glance the geologically complex nature of this prospect. One obvious feature of this fault interpretation exercise was the iterative nature of the task of picking fault segments on each of the seismic sections. Wrongly picking or omitting or wrongly assigning fault segment would distort the final result of the interpretation (Jonah, 2000).

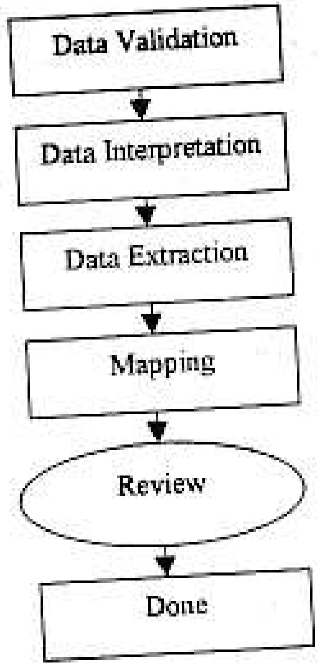


Fig. 4: Work Process Plan

Naming Identified Structures.

The first step employed towards obtaining the information needed from seismic section was to start the process of deciding what it means. Horizontal, to near-horizontal surfaces and vertical outlook of the seismic section infer different features that may not be totally correct or that the interpreter may not be able to totally observe and give correct meaning to. In every seismic section, different kinds of structures are present or observable and in most cases these structures can give a geologically detail of the study area without actually carrying out detail work on the area. However, with a pre-knowledge, identification becomes easy and the faults are identified and named. The erosional surfaces are marked and all other visible structure that can be interpreted are noted and marked. Fig.5 illustrates a visible fault on a seismic section showing a change in the dip direction of the horizon and the amplitude variation due to compaction change in sediment layers as we go from top to the bottom on the study area.

Correlating The Identified Structures

The seismic section interpreted was made up of two basic lines namely, the dip lines and the strike lines. These lines intercepted each other at different points along the shot point. The structures identified on each line were noted and marked on each section. The structure marked on one section was then checked on the next line to see whether it continued. If the fault traced on Fig.5 is observed on the next line, then the fault is then said to correlate and it can be carried along as the same structure on that line and it continues to bear the same name or identity until it cannot be seen to be visible on any other line again. In other words the observed structure was overlaid or juxtaposed on the other structure and on the other section to show its continuity.

Selecting a Reflection Horizon

Generally, before picking a reflection horizon one must look through all carefully through all the sections for a place or point where the reflection is most clear and continuous and start there. Seismic sections are characterized by amplitudes that are made up black peaks and white troughs, with a zero crossing between them showing at close range the peaks and through and the zero crossing indicated by the vertical line (Fig.6). For the sea-floor where the continuity of the reflection is assured, the horizons were marked with fine colored pencils (blue for the first horizon in the case for this study and green for the second horizon) with a steady hand.

Timing And Tying of Looped Horizons

When picking the black and white transition (peak and trough) on each seismic section, checks were constantly done to ensure that the horizons being interpreted were the same as that on which the reflection picking was initiated, and ascertained to lie at the same intersection (where two lines crossed). The lines running N-S are the dip lines, and those running E-W are the strike lines. Where they cross each other, the time and subsurface character are the same. This timing and tying was done overlaying (juxtaposing) one line above the other and the time and horizon at the point were the same to show the clear continuity obtainable in the environment. Fig.7 shows the tie at an intersection.

Posting

After horizon interpretation, loop-tying, and timing of the horizons were completed, the actual two–way travel times for the event that corresponded to the geologic horizon being mapped were posted from the seismic section to the basemap. The same two-way travel times can be posted for any fault surfaces being mapped (Tearpock & Bischke, 1991).

Contouring

The majority of the subsurface maps use the contour line as the vehicle to convey the various types of subsurface data. Usually, this value is compared to some chosen reference, such as sea level in the case of structural maps. After the posting of the two-way travel time on the basemap and the corresponding two-way travel time for any fault surfaces, the process of contouring the time value becomes very important. The contouring was done by timing the horizons on a particular seismic section, say line 82 – 455. On this particular seismic section, all other sections that intersected and crossed line 82 – 455 were located at an interval of 10 shot points. The time at the horizon was then looked up on the check shot survey graph to determine the corresponding depth. When all the 10 shot-point intervals on the seismic sections were properly timed and converted to depth, the values depth were then posted to individual seismic lines on the basemap. The values transferred from the seismic section to the basemap were values ready for contouring. Equally, all values converted to depth on the fault surfaces were transferred to the

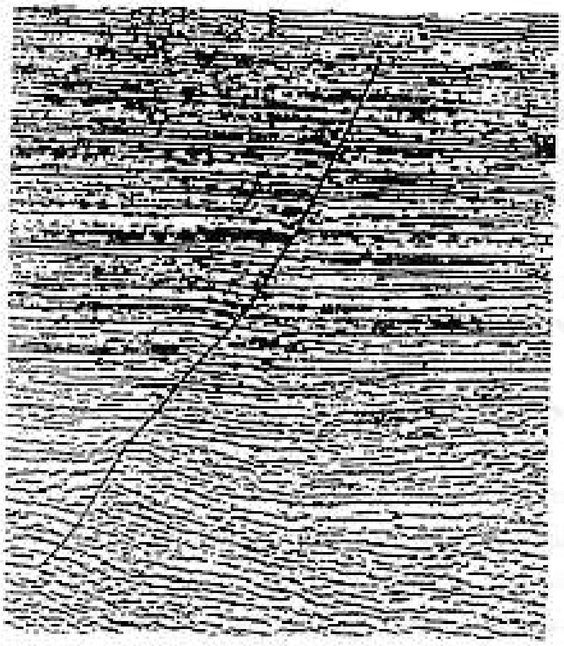


Fig. 5: Section Showing Change in Dip Direction

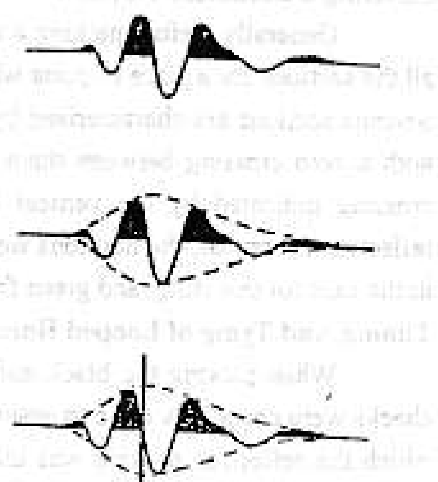


Fig. 6: Typical Seismic Trace Showing Peak Through and Zero Crossing

Fig. 7: Seismic Section Tie at an Intersection

basemap and this helped in the location of the fault position and dip direction on the basemap. After the transfer was finished, contouring was begun using as a guideline the contouring rules. Since a contour line cannot cross itself or any other contour, points of equal values only were connected and it was ensured that the line that pass between two other lines was lower than the one above and higher than the one below as the case may be. The process employed for converting the values involved looking up the depth values corresponding to the posted time values in a time-depth table that has been generated from checkshot data. Figs. 8 and 9 are the contoured depth structure map of this study area.

Geologic Cross-Section

In constructing the cross-section across the two horizons on the two depth structure maps, a section was drawn through the straight line marked A-B on the line 82–451 shown on the contoured depth structure map as a point slice representative of the subsurface body. The points from the depth structure map were located on the graph sheet to show the exact point in accordance with the point on the structure depth map which were connected to show the fit. The two horizon cross section were drawn on the same graph sheet to show the exact point of the formation in relation to depth from the seismic section and well log data. Geologic cross sections constitute a very important geological exploration and exploitation tool and are useful in all phases of subsurface geological studies in solving structural problems. A typical example of such an illustration is presented in Fig.10 for the case of a diapiric body of shale that is indicative of probable prospect well site with a estimated depth of about 6500ft.

DISCUSSION OF RESULT

The first objective of this interpretation exercise was to correctly identify hydrocarbon-bearing sands on the dip seismic sections and also to properly follow this sand through in the strike directions. The sands were correctly identified on the dip sections by the technique of the well-to-seismic tie. Two major hydrocarbon- bearing horizons were identified as "Blue Horizon" and "Green Horizon". These two horizons show the basic requirement for picking during the cause of the work. Starting from seismic data generation that was pointed out to be based on airgun survey, the interpretation commenced in stepwise mode by first identifying the structures to be interpreted, picking of faults in the identified structure. Having done this, the identified structures of interest were correlated, timed, and loop-tied before posting. Contour maps of the horizons of interest were next produced, and finally a geologic cross-section through the contoured horizons was produced.

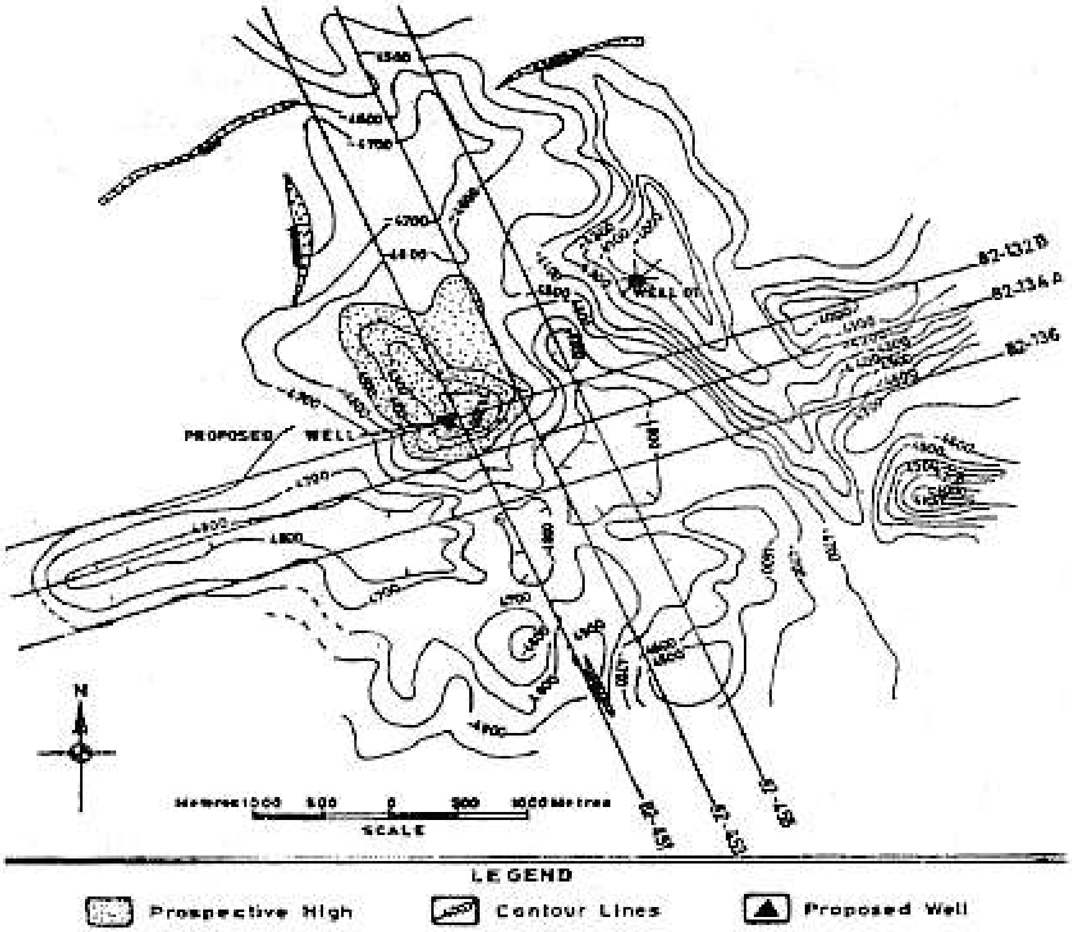


Fig. 8: Seismic Interpretation and Hydrocarbon Potential of Igbokoda Field (Offshore Location)

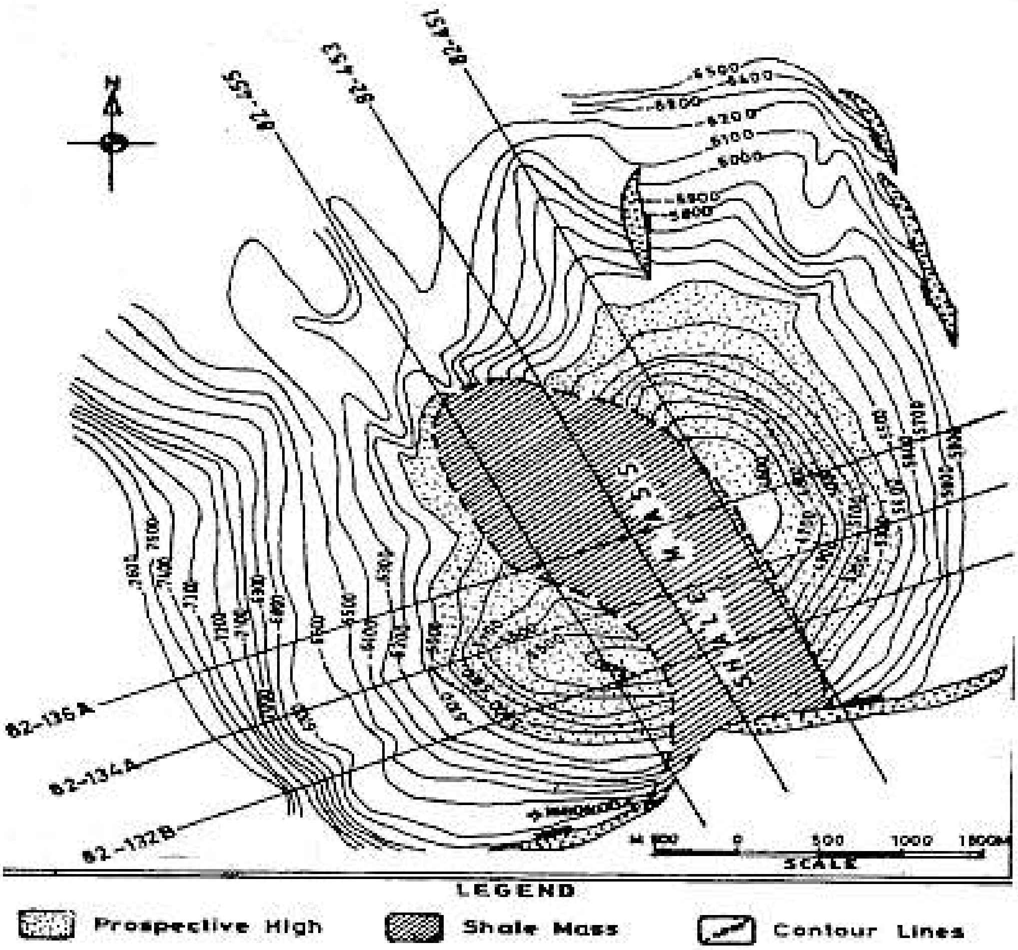
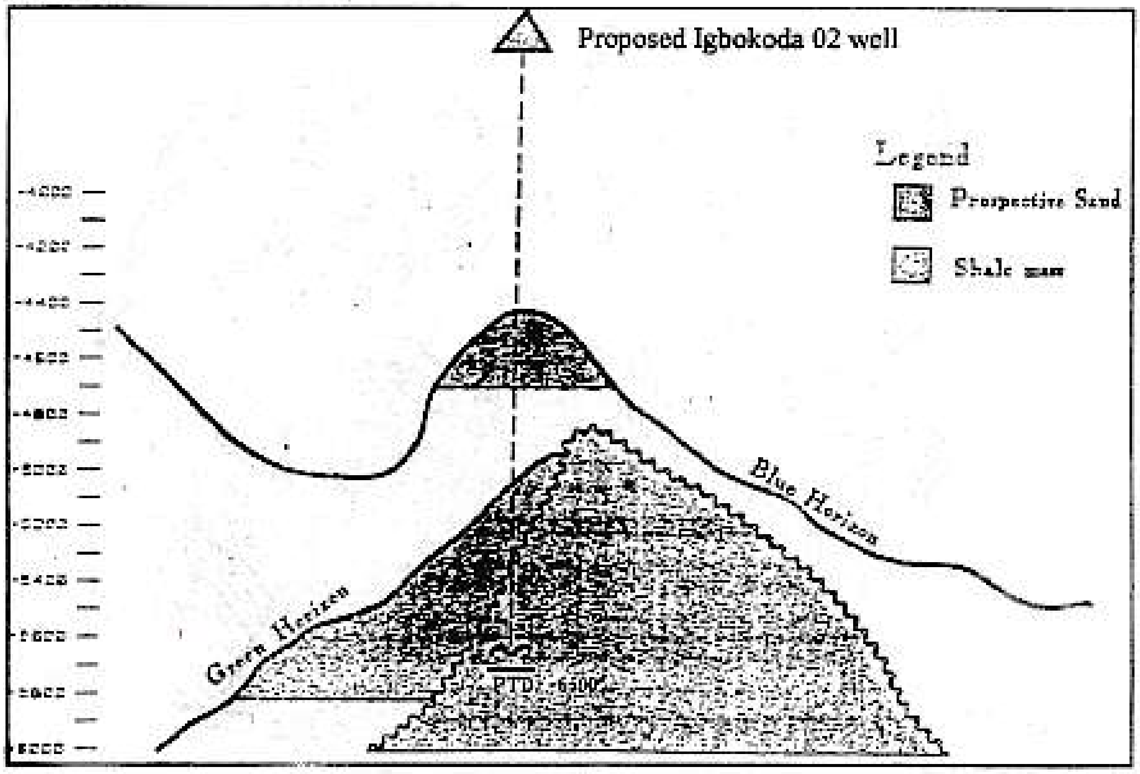


Fig. 9: Seismic Interpretation and Hydrocarbon of Igbokoda Field (Offshore Location)

Cross-Section A-B Showing Prospective Section



MOBIL PRODUCING NIGERIA

IGBOKODA
Cross-Section A-B Showing
Prospective Section

Fig. 10: Cross-Section of A-B

CONCLUSION

There are two reservoirs (called Blue and Green horizons) in Igbokoda field. The major and the most difficult problem was the quality of the available data for the interpretation. The prints were very poor, thereby making certain evaluation hard and prolonging the time spent on the seismic section. The absence of a workstation played a big role in the fact that the process of using a synthetic seismogram for comparison was completely ruled out in this interpretation.

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