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RESERVOIR CHARACTERIZATION AND STRUCTURAL INTERPRETATION OF SEISMIC PROFILE: A CASE STUDY OF Z-FIELD, NIGER DELTA, NIGERIA

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Abstract

3D seismic data and well logs have been used to map the structure and stratigraphy in Z-Field Niger Delta where identification of reservoir facies is a major challenge to plan delineation and development drilling. A network of faults and four horizons, A, B, C and D were identified and mapped. Time and depth structure maps of the top of the reservoir of interest show the hydrocarbon bearing structure is a fault-assisted anticlinal dependent structure. Gamma ray and resistivity logs in four exploratory wells were utilized to delineate formation lithologies (facies). The target horizon C (top of sand) was selected for seismic structural mapping. Two major faults (F1, F2) were identified on the time and depth structural maps and a network of other fault structures were identified and interpreted on the seismic sections. The quality of the reservoirs in the "Z-field" Niger Delta is moderate to good and in some distal reservoirs, they are excellent. The average porosity values are approximately the same, but have variations in permeability which could be as a result of compaction of the older reservoirs on the proximal part of the field (Wells A-20 & A-30).

Key words: seismic; structure maps; hydrocarbon; stratigraphy; porosity.

1. Introduction

The geophysicist and geologists have shown that the Niger Delta Basin has spectacularly maintained a thick sedimentary apron and salient petroleum geological features favourable for petroleum generation, expulsion and trapping from the onshore through the continental shelf and to the deepwater terrains. Presently the challenge before upstream petroleum industry is to accrete reserves from stratigraphic prospects. Exploration and exploitation of these prospects need careful and cautious planning. The characterization of reservoirs requires the integration of different types of data to define reservoir model. Seismic data can contribute to a well defined geometric description of structural and stratigraphic aspects of the reservoir. To achieve this, meaningful interpretation of seismic data needs be displayed in depth since the primary geophysical seismic data is recorded in time. The primary objective of geophysical seismic interpretation is therefore to prepare contour seismic maps showing the two way time to a reflector as picked on the seismic sections. This time (isochron) map must be converted to depth (isodepth) map through the seismic time-depth conversion process.

The objectives of the present work are to make detailed use of available wireline log data to delineate the reservoir units in the wells in the field, determine the geometric properties (porosity and permeability) of the reservoir rocks, and infer reservoir geometry distribution and reservoir quality trends using the reservoir correlation. Detailed study of the petrophysical results of the field will provide an understanding of the geometric properties of the reservoirs, lateral variation in thickness and possible hydrocarbon accumulations.

2. Location & Geology of the Study Area

The Z- field is located onshore western Niger Delta, figure 1. The geology of the Tertiary section of the Niger Delta is divided into three Formations, representing prograding depositional facies distinguished mostly on the basis of sand-shale ratio [1,2,5]. They are namely Benin Formation, the Paralic Agbada Formation and Prodelta Marine Akata Formation. They range in age from Paleocene to Recent. The Benin Formation is a continental latest Eocene to Recent deposit of alluvial and upper coastal plain sands. It consists predominantly of freshwater baring massive continental sands and gavels deposited in an upper deltaic plain environment. The Agbada Formation consists of paralic siliciclastics, which underlies the Benin Formation. It consists of fluviomarine sands, siltstones and shales. The sandy parts constitute the main hydrocarbon reservoirs. The grain size of these reservoir ranges from very coarse to fine. The Akata Formation is the basal unit of the Tertiary Niger Delta complex. It is of marine origin and composed of thick shale sequences (potential source rock), turbidities sand (potential reservoirs in deep water and minor amount of clay and silt. Beginning in the Paleocene and through the Recent, the Akata Formation formed during low stands, when terrestrial organic matter and clays were transported to deep-sea water areas characterized by low energy conditions and oxygen deficiency [6]. It is the major source rock in the Niger Delta. The three lithstratigraphical units have been established in both the Onshore and continental Shelf terrains as the maim petroliferous units in Niger Delta of Nigeria.

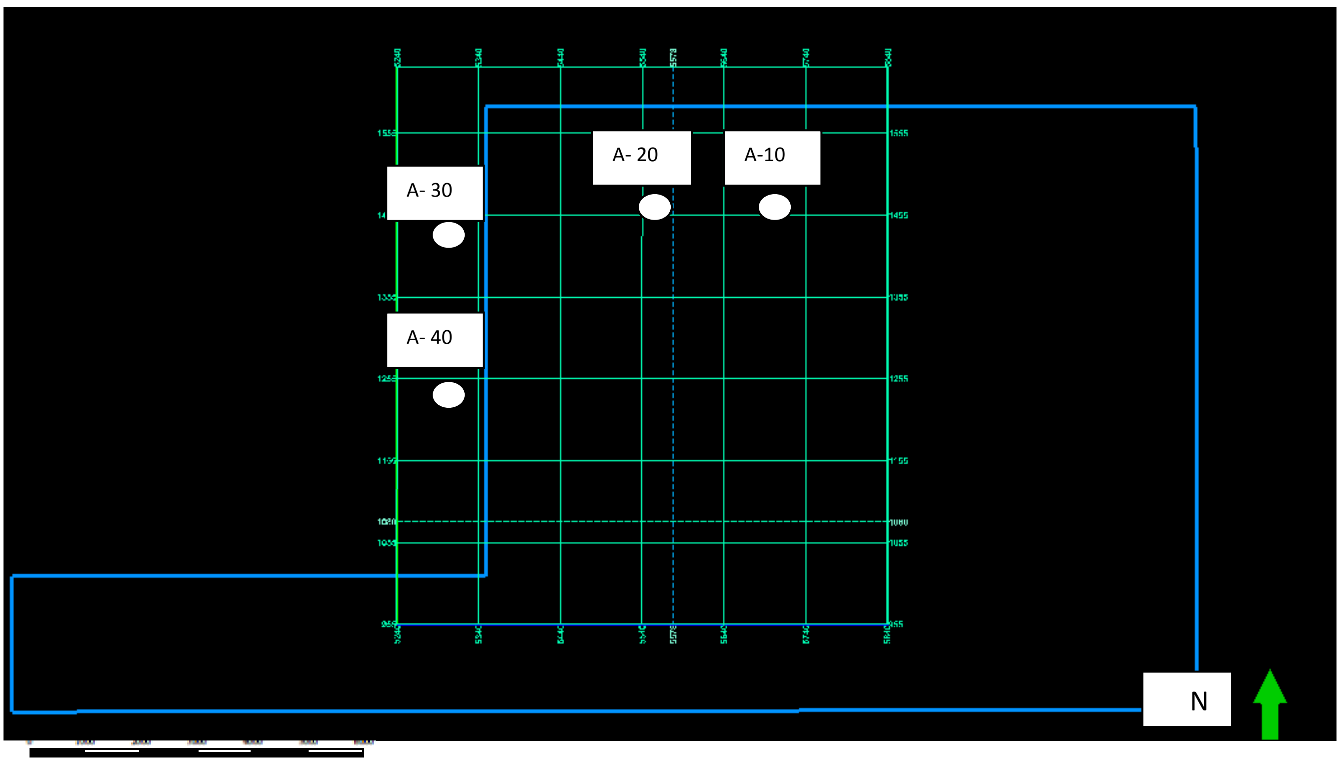

Figure1 Basemap of Z- Field Showing Well Locations and Seismic Lines.

3. Materials and methods

Petrel software was used to interpret the seismic data and to generate maps and well log sections. The main data comprised 3-D seismic sections and borehole data (gamma ray, resistivity and porosity logs). The gamma ray and resistivity logs were used to delineate lithofacies in two of the four wells. The target ‘C’ horizon was identified on both the well logs and seismic sections. The horizon was determined using the reflection characteristics of the 3-D seismic volume, stratigraphic indicators and the nature of the gamma ray curves that characterize this area. After correlation, time and depth structure maps were produced using the software. The time depth relationship was determined by plotting the checkshot data available for the well A-10 as well. Faults were also identified, traced, assigned and interpreted as fault planes.

4. Presentation and discussion of results

The 3D seismic data was interpreted on an interactive workstation. Four key horizons (A top, B, C, and D) were interpreted and mapped using their seismic continuity and adequate seismic to well correlation [Figure 2]. The results obtained from interpretation of only one horizon C are presented in this paper. Two seismic sections KK' (Inline) and CC' (Crossline) are shown in Figs. 2 & 3. Correlation of horizon C is shown on the sections. Time and depth structure maps (Figs. 5, 6) are prepared using the mapping workflow package of Petrel work-station. Depth map preparation was done using 3D seismic final migrated velocity grid corrected suitably with well velocity data. The time and depth structure maps are in conformity, thus indicating no depth anomaly due to velocity. Time slices and horizon slices were analyzed at every 3 ms interval in the zone where presence of reservoir (sand) was established from seismic calibration. Finer structural details and seismic attributes derived from 3D data were integrated with well data and prospective areas were identified. A number of E-W trending cross faults in addition to a NE-SW trending fault are mapped. Fault correlation on section has been shown in Fig 3. Composite suite of logs comprising gamma ray, porosity, resistivity logs [fig.4] were run in wells (A-10 and A-40) and acquired for log interpretation to estimate the reservoir characteristics.

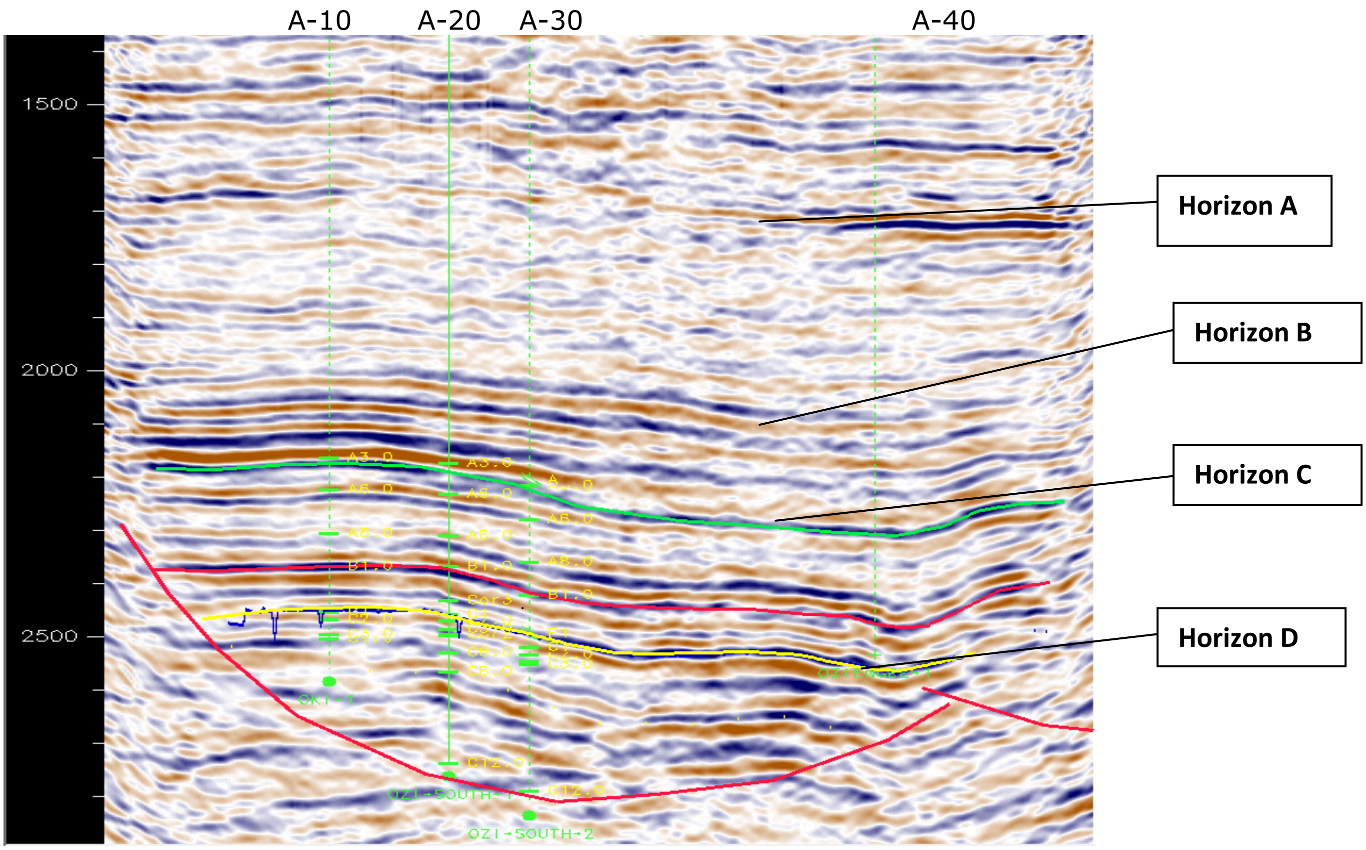

Figure 2 Seismic section KK' showing the four wells and their respective gamma ray and resistivity logs, stratigraphy, faults, horizons and seismic reflection characteristics of the study area.

Figure 4 shows the interpreted hydrocarbon-bearing reservoir formation (sandstone) located in well A-10 delineated using the combination of gamma ray and porosity logs. The reservoir sandstones were deposited by fluvial /estuarine channels which incised older sand/silt sequences. The four wells located within the field, penetrated two different lithological zones. The first zone lies between the depth intervals 1750 ft [530.30 m] to 1950 ft [590.91 m], and predominantly made up of thick shale bodies with a thick interbed of fine sand and thin interbed of carbon layers [Figure 4.]. The second zone extends from the depth of 1950 ft [590.91 m] to about 2100 ft [636.36 m] where the sandstone beds are predominant and are intercalated with thin sequence of siltstone. The entire borehole can be regrouped into upper and lower parts. The upper part shows a characteristic where the shale beds are thicker, whereas in the lower part, a reversed situation is the case. As expected, the shales and clays which contain very fine-grained particles exhibit very high porosities. However, because the pores and pore throats within these formations are so small, they exhibit little or no permeability and therefore serve as seal for the underlying sandstone reservoir. The lower sandstone sequence exhibits high permeability and serve as reservoirs for the accumulation of oil and gas. Generally, the porosity/permeability values of the sandstone reservoirs in the field are good enough to accommodate large hydrocarbon yield, but these characteristics tend to improve significantly as sedimentation proceeds basinwards.

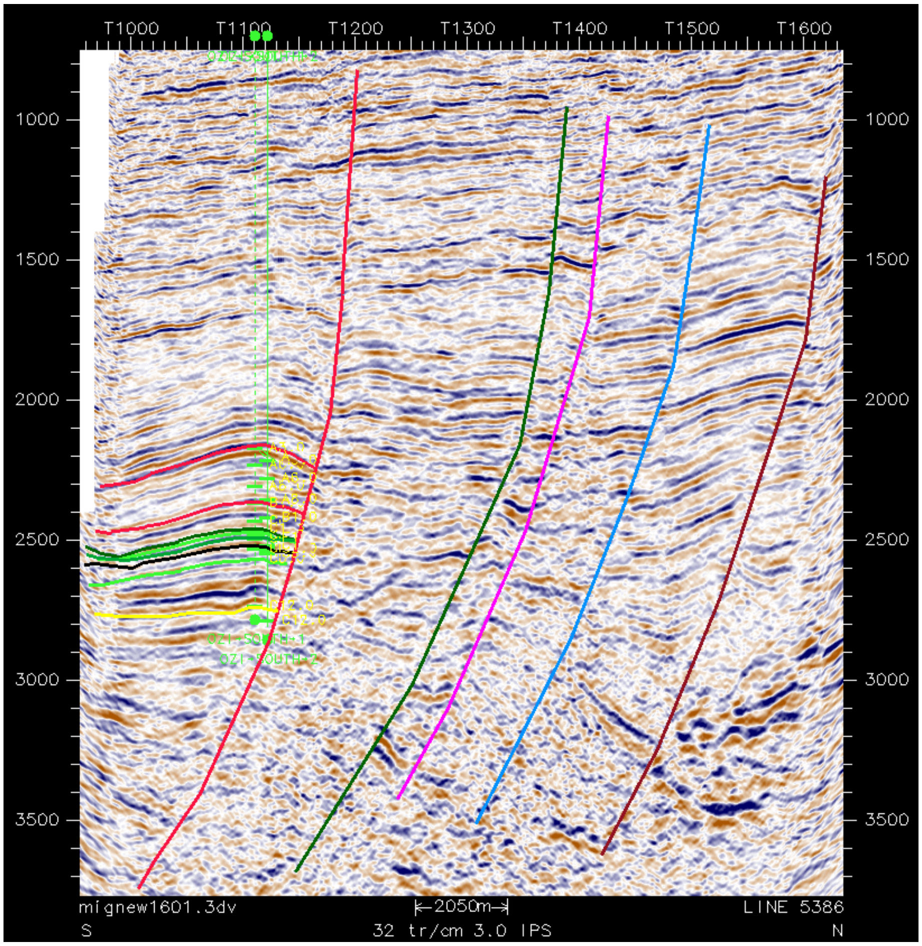

Figure 3 Seismic section CC' showing network of fractures and well A-10

Post depositional fault control structure forming is evident in the area. The structure maps indicate NE-NW trending high and low features in the southern part with terrace feature in the central part of the area. Figure 5 is the seismic structural time map of the target C-surface. Both types of structural contour maps show similar structural relationship. Two faults, F1 and F2, were delineated on the seismic sections. F1 is the growth fault (major structure) that bound the field. F1 is characterized by an east-west trend and curved in shape while F2, the minor fault is trending towards the south from the western part of the field. They both strike northeast-southwest and dip south directions. The average velocities derived from sonic logs were used to convert the target seismic C-surface to depth [Figure 6]. The trapping potential of the field can be attributed to faults or anticlines, acting either as fault assisted or anticline closures respectively [3,4]. Anticlinal and fault assisted closures are regarded as good hydrocarbon prospect areas in the Niger Delta [7]. Trapping of hydrocarbons in an anticline is simply by means of closure which may be dependent or independent on faults. The rollover anticlines [red portions] are formed on the downthrown block of the growth fault, which indicate structural closure in these areas [figures 5 and 6]. It can be deduced from this study that the wells were located to target the rollover anticline formed on the downthrown side of the growth fault. The oil and gas reserves recoverable deduced from the time and depth structure maps vary widely [7]. The height of oil above the spill- point and the geographic extent of oil pool are directly related to the type of closure in which the hydrocarbons are trapped.

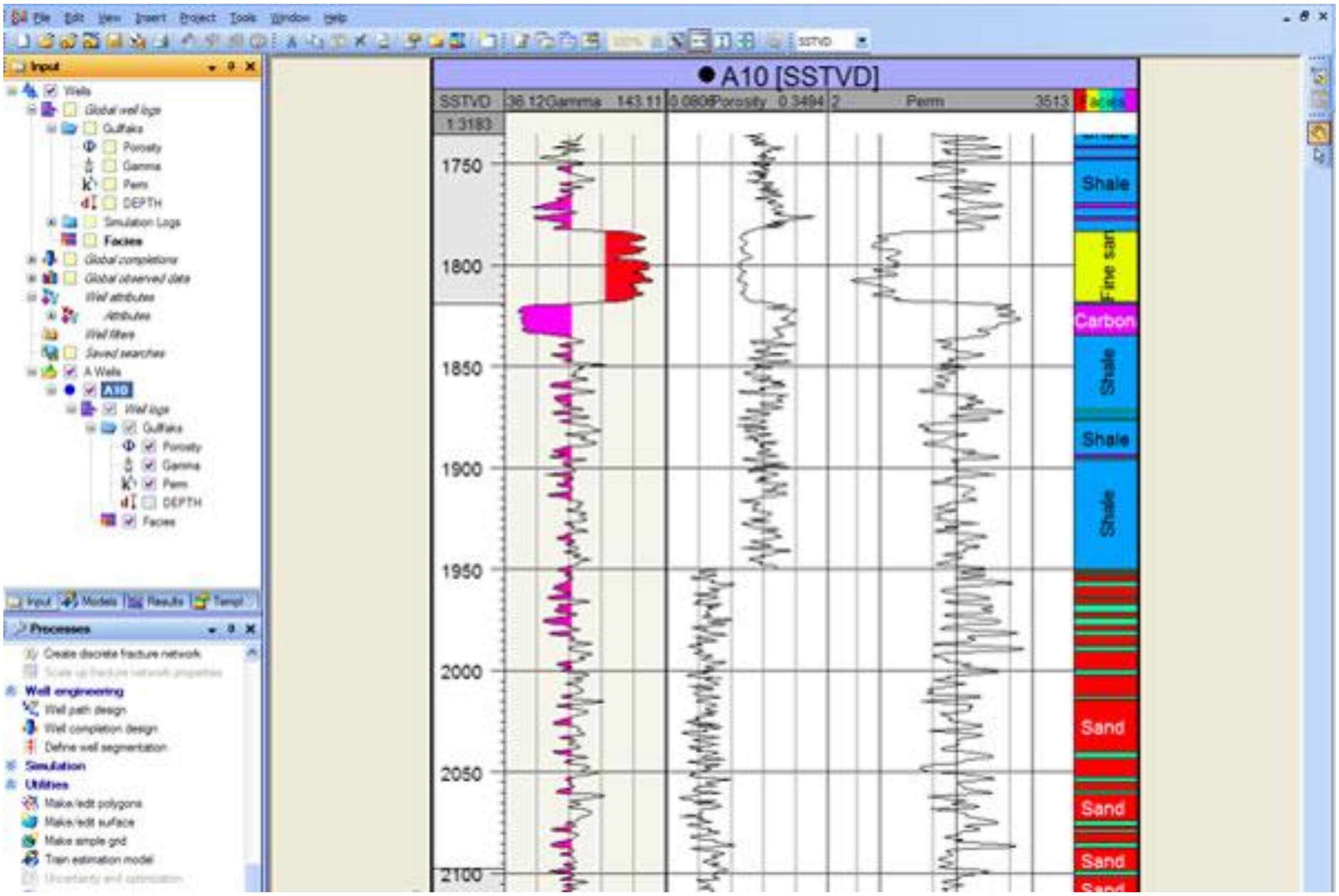

Figure 4 Gamma ray and porosity logs showing shale/ sandstone sequence

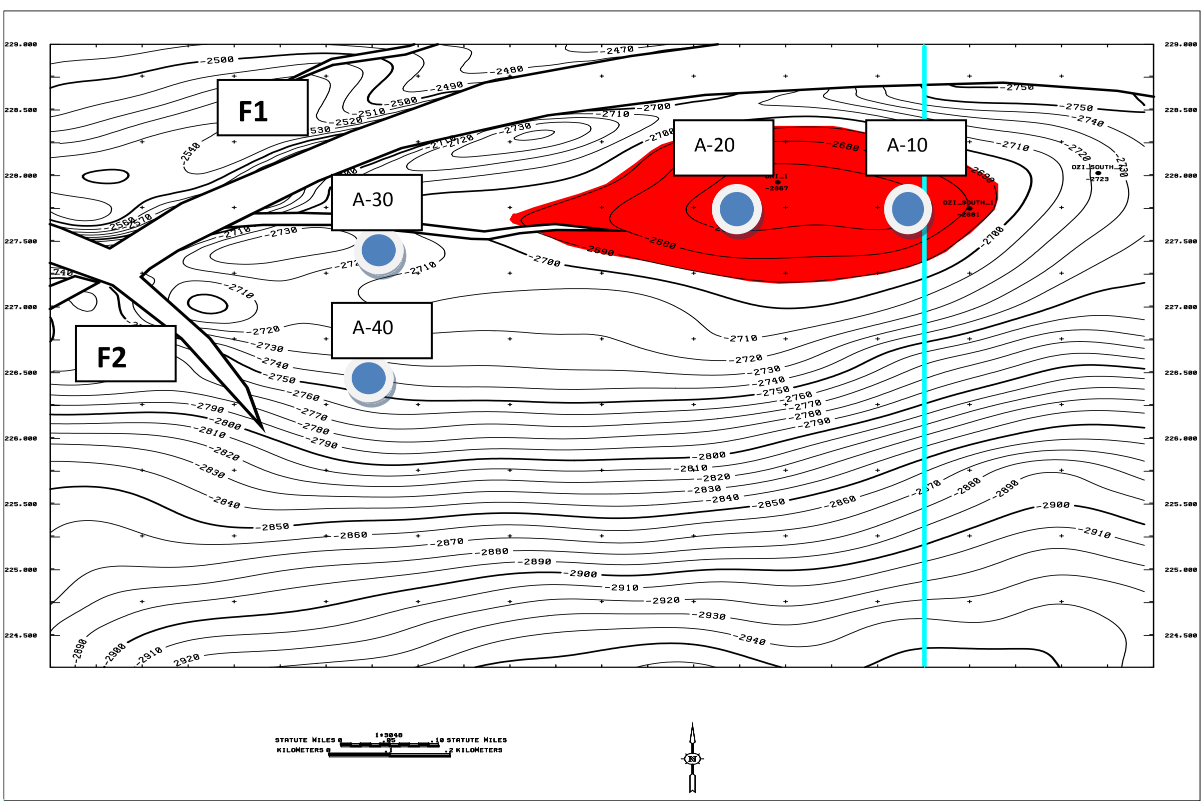

Figure 5 Structural Time Map of the target EF Horizon.

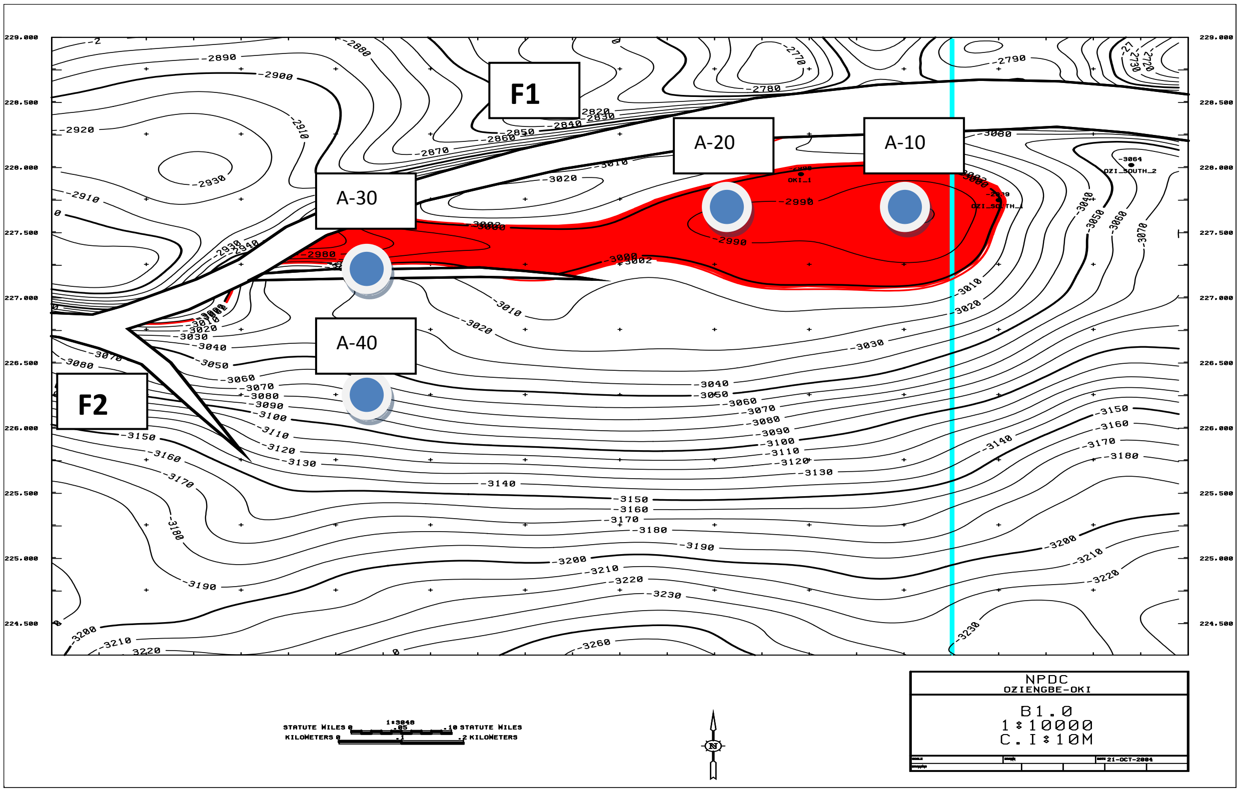

Figure 6 Structural Depth Map of EF Horizon derived from Sonic Velocity.

5. Conclusion

Seismic and well log data have been used to illustrate structural characteristics of identified sand bodies within the subsurface of the Z- field. This was made possible by creating time and depth structural contour maps of four horizons using the Petrel interpretational tool. The time and depth structure maps show subsurface structural geometry and possible hydrocarbon trapping potential. One major growth fault, F1 was observed to extend throughout the entire mapped area. The subsurface reservoir trapping mechanism of the area was revealed to be a fault-assisted anticlinal structure. This study, however, can provide additional information for precise well placement in further exploration and production of oil and gas.

Within the limits of the available data, it is recommended that further studies should include integration of velocity (check shot) and biostratigraphic data of all the wells. This will provide more reliable data for interpretation of the depositional environments.

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