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Hydrocarbon Prospectivity Evaluation of 'Honyx' Field, Niger Delta

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ABSTRACT

3D seismic data, checkshot data and suite of well logs for 4 wells were analyzed with Petrel software for the hydrocarbon prospectivity evaluation of the field. The method adopted involved delineation of lithologies from the gamma ray log, identification of reservoirs from the resistivity log, well correlation, determination of petrophysical parameters, horizon and fault mapping, time to depth conversion, attribute analysis and reserve estimation. One reservoir was mapped from the well logs. The petrophysical analysis gave porosity value of 0.24. The S_h value for the reservoir is 0.62. A horizon was mapped and two faults were picked. The depth structure maps generated showed an anticlinal structure at the centre of the surface and the mapped faults with the 4 wells located on the anticlinal structure. Sweetness attribute was extracted on time slice close to the surface which also shows the location of the bright spot. The reserve estimate for the reservoir is 40.1mmbls. The results of the petrophysical analysis revealed the presence of hydrocarbon in the reservoir at quantities favourable for commercial exploitaton. The result of this analysis has proved that the integration of attribute analysis with structural interpretation is a reliable and efficient way of carrying carrying out hydrocarbon prospectivity evaluation of any oil field. It has also enhanced hydrocarbon exploration for optimal well placement and reserve estimation.

KEYWORDS Bright Spot, Sweetness Attribute, Depocenter, Petrophysics, Traps

INTRODUCTION

The need to thoroughly evaluate prospects so as to determine optimal production strategies and also minimize risk that may be associated with hydrocarbon exploration has driven the development of an array of techniques which attempt to propagate log properties (Obiadi *et al.,* 2016).

Seismic and well log data are widely used in petroleum exploration to map the subsurface. The two data sources are complementary: seismic profiles provide an almost continuous lateral view of subsurface, whereas well logs yield fine vertical resolution of the geology at the borehole (Omoboriowo *et al.*, 2012). Seismic profiles can resolve, with relatively high precision, the structural and stratigraphic changes from the arrival times and amplitudes of the reflection events. Reservoir characterization is one of the most important steps in exploration and development phases of any prospect (Abe and Lurogho, 2020). Seismic attributes analysis involves the procedure used to extract corresponding subsurface geological information from seismic sections (Aigbedion and Iyayi, 2007). Seismic attributes are extensively being used in the oil industry to predict subsurface reservoir properties (Abe and Olowokere, 2013). Integration of 3D seismic model with petrophysical data has been a beneficial endeavour in use in the petroleum industry for some years now (Adeoye and Enikauselu, 2009). In petroleum provinces where exploration and production strategies merge, detailed understanding of petrophysical properties is highly desired (Emujakporue, 2016). Seismic attributes are used in most seismic exploration and reservoir study to correctly image the subsurface geological structures, correctly characterize the amplitudes of the seismic data and to obtain information on reservoir properties (Abe *et al*., 2016). Seismic attributes analysis also offers clues to lithology typing, estimation of layer porosity, fluid content, mitigation of stratigraphic and structural features, drilling risk, reservoir characterization, and better identification and definition of sweet spots.
Seismic attributes are quantities of geometric, kinematic, dynamic, or statistical features obtained from seismic data (Ologe*,* 2016). The geometrical seismic attributes can enhance the visibility of the geometrical characteristics of seismic events and are sensitive to the lateral variation of azimuth, continuity, similarity, curvature, energy, and dip (Ologe and Olowokere, 2021). Prospect generation therefore is related to efforts for defining lead and it usually involve geological and geophysical interpretational process related to fine-tune the subsurface lead and identifies the existing risks associated with the prospect.

Location of Study Area

The study area lies within the Niger Delta. Figure 1 shows the base map of the study area. The delta is one of the major regressive deltaic sequences of the world and is located in the Gulf of Guinea on the west coast of Central Africa, north of the equator between Latitude 4^0N and 6^0N and Longitudes 3^0E and

9^0E in the southern part of Nigeria. It has a maximum thickness of 12,000m and occupies an area of 75,000 Km^2.

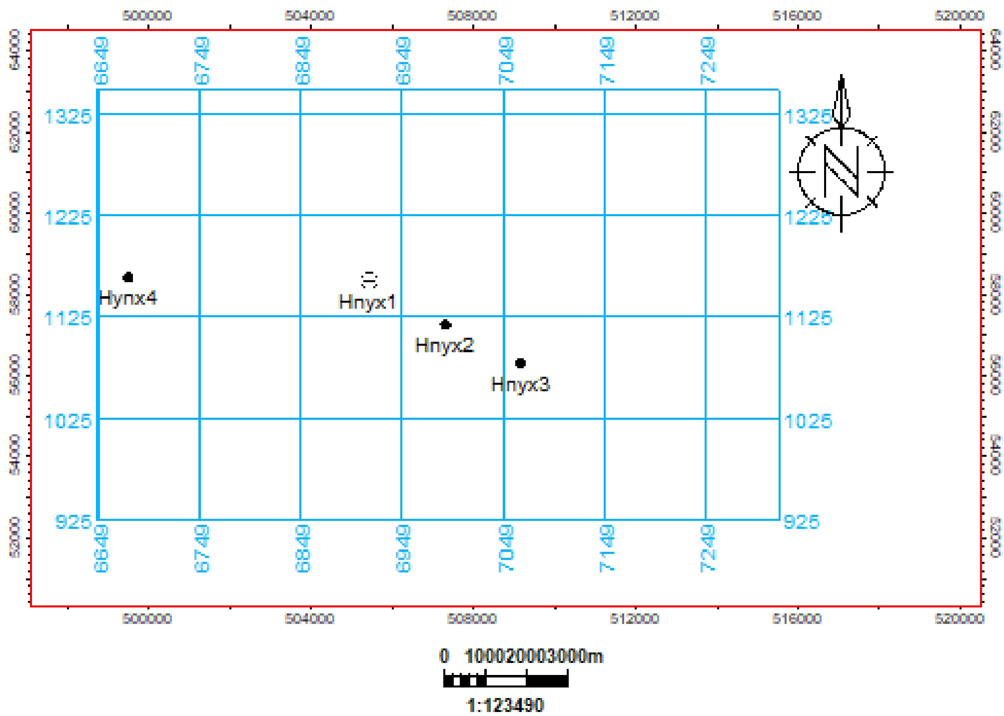

Figure 1: Base Map of the Study Area

Geology of the Study Area

The Niger Delta is a large acute delta of wave-dominated type and is composed of clastic sequence which reaches a maximum thickness of about 12 km in the basin center (Aizebeokhai and Olayinka, 2011). It is bounded in the west by the Benin flank and in the east by the Calabar flank, a subsurface expression of the Oban massif (Stoneley, 1966). The deep offshore is situated over oceanic crust emplaced during Cretaceous–Paleogene first related spreading of the South Atlantics. Offshore boundary of the province is defined by the Cameroon volcanic line to the east, the eastern boundary of the Dahomey basin to the west, and the 2 km sediment thickness contour or the 4,000-m bathymetric contour in areas where sediment thickness is greater than 2 km to the south and southwest. The province covers 300,000 km^2 and includes the geologic extent of the Tertiary Niger Delta (Akata–Agbada) petroleum system (Michele *et al*., 1999). The lithology of the Niger Delta shows an upward transition from Akata Formation (marine pro-delta shales) through Agbada Formation (paralic interval) to Benin Formation (continental sequence). The three sedimentary environments (Figure 2) extend across the whole delta and ranges in age from Upper

Cretaceous/Early Tertiary to recent. A separate member (the Afam clay member) of the Benin Formation is recognized in the eastern part of the delta and is considered as an ancient valley fill formed in Miocene sediments (Nyantakyi *et al*., 2013). Initial sedimentation in the offshore began within Upper Cretaceous–Lower Oligocene hemipelagic mudstones of the Akata Formation. Late Oligocene through recent progradation of the Niger Delta into the slope rise environment allowed for turbidite deposition of the more coarse-grained siliciclastics of the Agbada Formation. The latter contains the lower and middle Miocene reservoir seal couplets responsible for the major deep-water hydrocarbon accumulations discovered to date. The underlying Akata Formation is believed to contain the main source intervals. The oil accumulation of the Niger Delta basin is generally confined to various levels of the Agbada Formation. The age of the productive sand interval varies from Eocene to Pliocene becoming progressively younger from north to south (Ejedawe 1981). This formation is the major petroleum-bearing unit in the Niger Delta basin, as there is presence of source and reservoir or seal rock with both syngenetic and epigenetic (derived from Akata Formation) hydrocarbon.

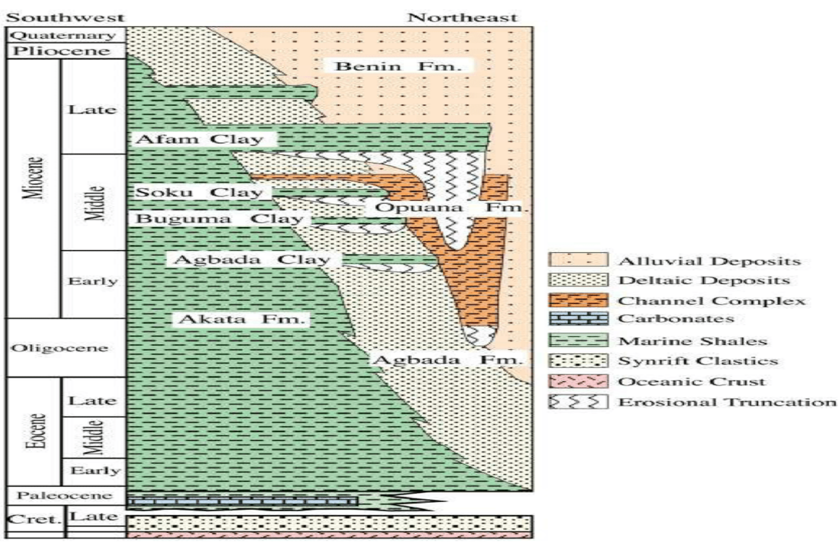

Figure 2: Stratigraphic column for the three formations of the Niger Delta. (Modified from Shannon and Naylor (1989) and Doust and Omatsola, 1989).

METHODOLOGY

The methods adopted in this research include delineation of lithologies and identification of reservoirs from the log signatures of gamma ray and resistivity logs. Fault mapping was done on the vertical seismic display across the whole seismic volume. Seismic to well tie was done to match events on well logs to the specific seismic reflections. Horizons were mapped, autotracked and converted to surfaces to obtain the time structure maps. The time structure maps were converted to depth structure maps using the checkshot data provided. In order to enhance the hydrocarbon potential of the field, seismic attribute analysis was carried out. The hydrocarbon pore volume was then estimated.

RESULT AND DISCUSSION

Petrophysical Evaluation

Two lithologies were delineated from the gamma ray logs which are sand coloured in yellow and shale in ash colour. Deflection of the gamma ray to the left associated with high resistivity signifies the reservoir intervals. Well correlation panel across 'Honyx' well is showed in Figure 3 with the reservoir having appreciable uniform thickness across the wells. The estimated petrophysical parameter is showed in Table 1, the thickness of the reservoir is 105.57 m. The porosity is 0.24, while the water saturation is 0.38, with hydrocarbon saturation of 0.62. The reservoir parameters obtained showed that the reservoir is good and of high quality.

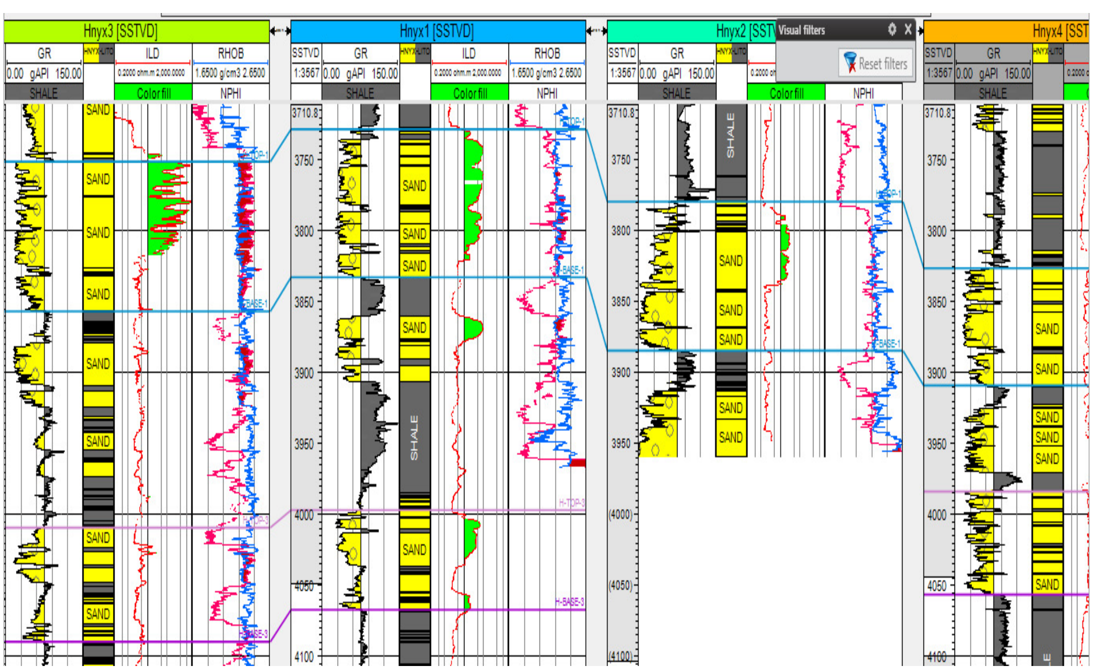

Figure 3: Well Correlation Panel across the Wells

Table 1: Estimated Petrophysical Parameters

	Top (meters)	Base (meters)	Vsh	Porosity (φ_D)	S_w	S_h	Permeability (mD)
	3763.94	3869.51	0.098	0.24	0.38	0.62	1300

Seismic Interpretation

The seismic data was imported to the interpretation software and seismic to well tie was done to in order to transfer the reservoir tops to the seismic section. Synthetic seismogram was generated in order to ensure that the proper horizon is picked. An interpreted seismic section showing the horizon mapped and some interpreted faults is showed in Figure 4. Faults interpretation was carried out, which involves the picking of faults. The faults are characterized by increasingly thicker hanging wall sequences of sediments as depth increases. A horizon was mapped across the inlines and the crosslines. It was mapped at 2618.91ms on the seismic line and this corresponds to a depth of 3166.00 m (10385ft) on the well logs. The reflector character can be easily seen on the seismic section. It is structurally controlled by growth fault in the area.

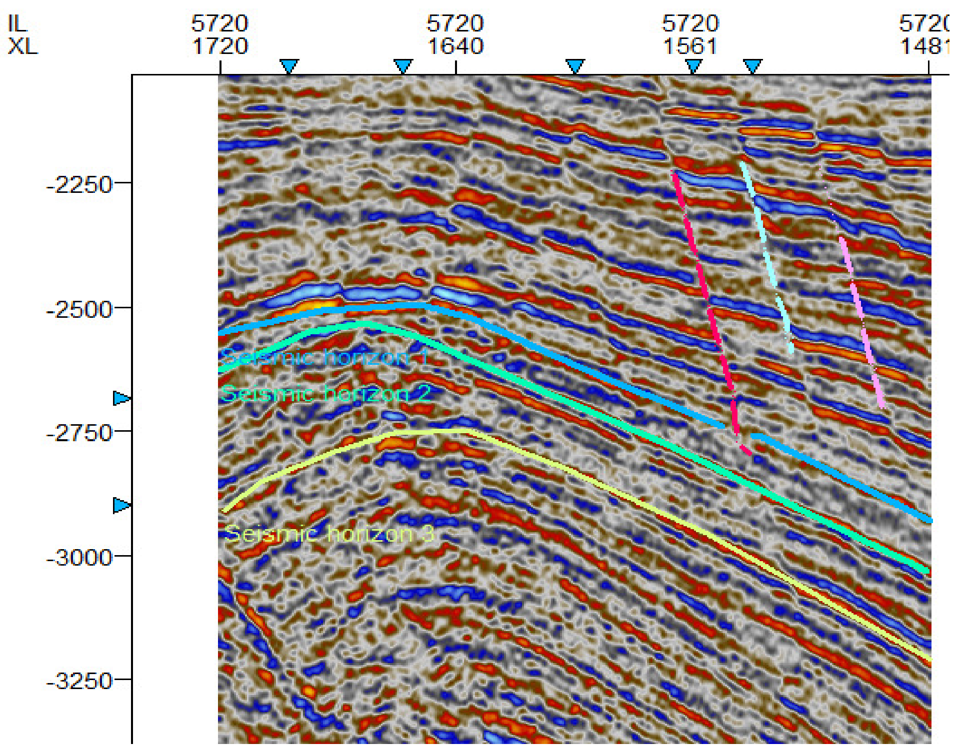

Figure 4: Seismic Section showing picked faults and mapped horizon.

The horizon mapped was autotracked and used to generate the time structural map showed in Figure 5. Variance attribute was extracted close to the mapped horizon in order to enable the mapping of the faults on the structural map.The contour values ranges from 2700 ms to 3250 ms. The lowest contour values on this map are found at the north-eastern part with values ranging from 2700ms to 2750ms, the major structures delineated are anticlines associated with growth faults. Two major faults were observed, both well pronounced. The crest of the anticlinal structure is a structural high and may be a possible hydrocarbon prospect. It is observed that the existing wells in the field were close to the flank of the mapped structural high implying conformity with existing interpretation.

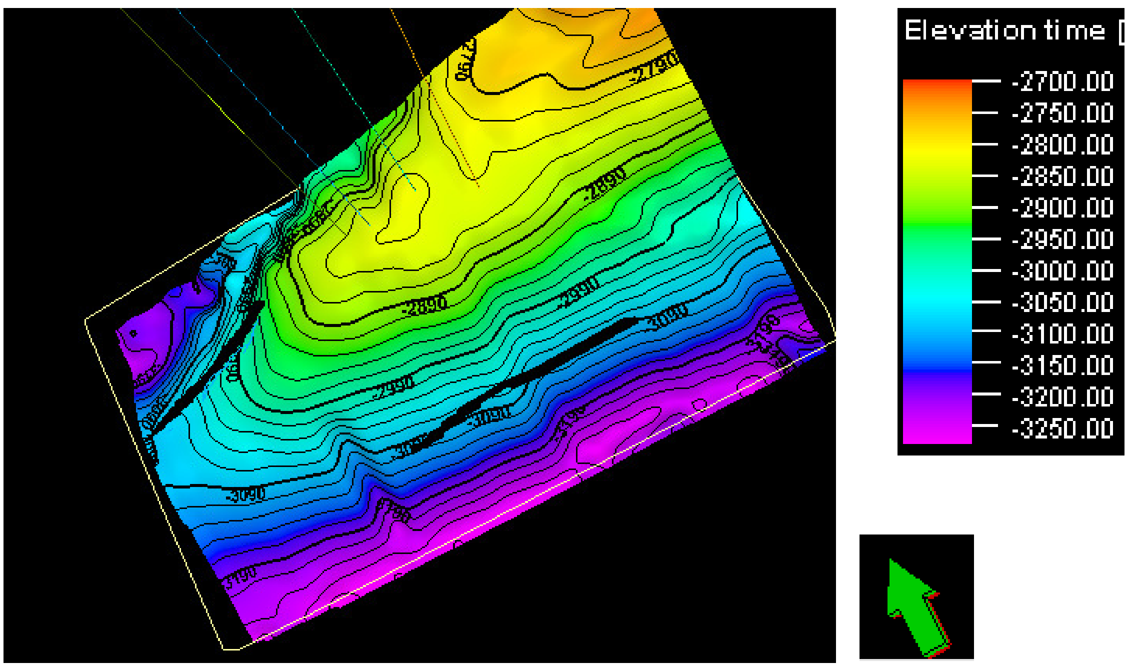

Figure 5: Time structure map with wells on Surface

The time structural map was converted to depth structural map using checkshot data. The data was plotted as showed in Figure 6 to obtain a polynomial relationship that enabled the conversion. The depth structural map is showed in Figure 7.

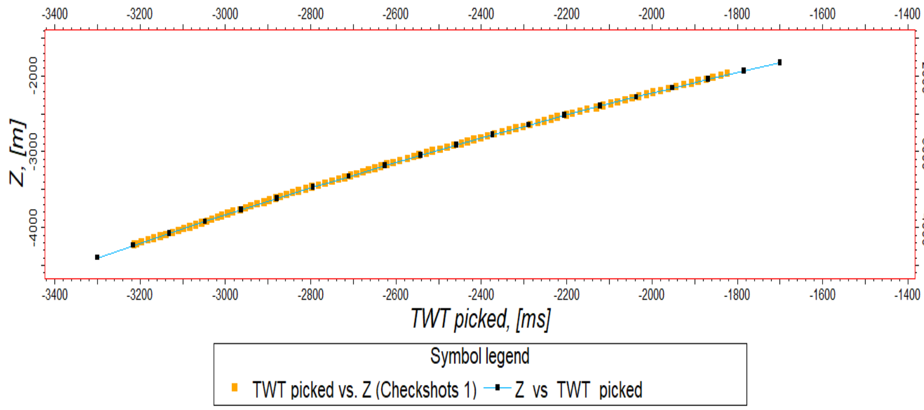

Figure 6: The time to depth relationship

The depth structural map showed depth ranging from 3300 m to 4300 m. The contour interval is 50m and the structural high with the anticlinal structure is still evident on the map.

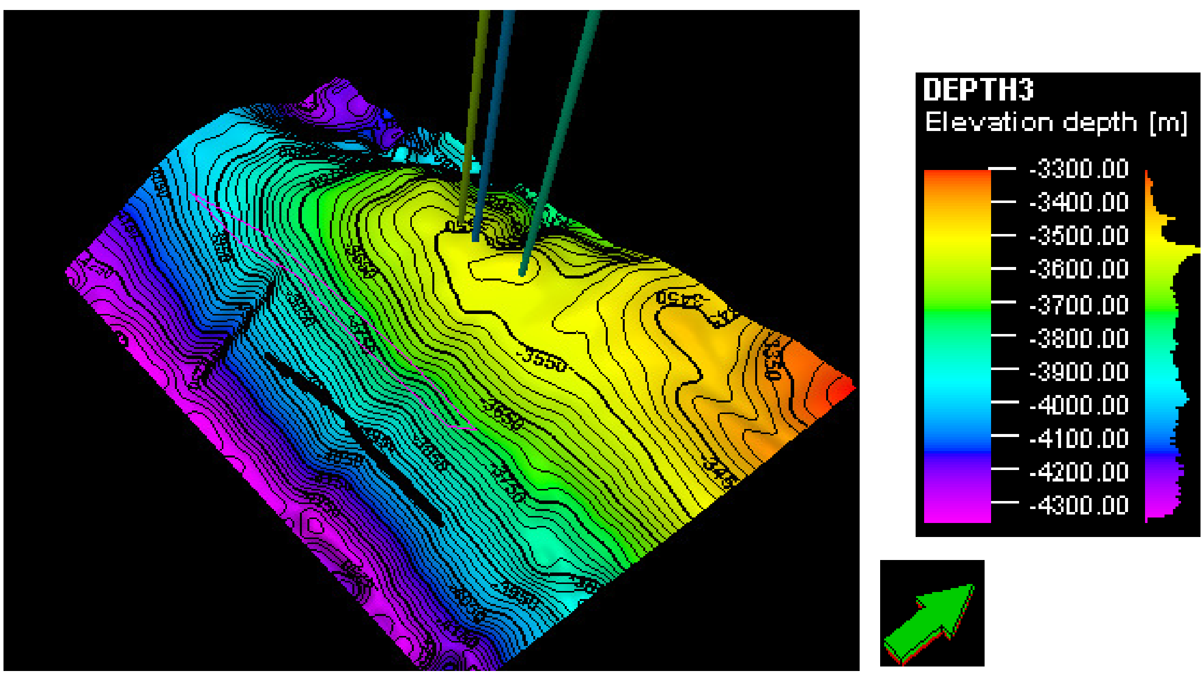

Figure 7: Depth Structure map on Horizon 3

Attribute Analysis

Volume attribute was extracted close to the surface in order to know if attribute is conformable with structure. Sweetness attribute which is a good hydrocarbon indicator was extracted as showed in Figure 8. The map showed that the region with anticlinal structure on the structural high is associated with high sweetness and amplitude which suggest that there is the possibility of the presence of hydrocarbon in it. The hhydrocarbon pore volume was then estimated to be 40.1mmbls.

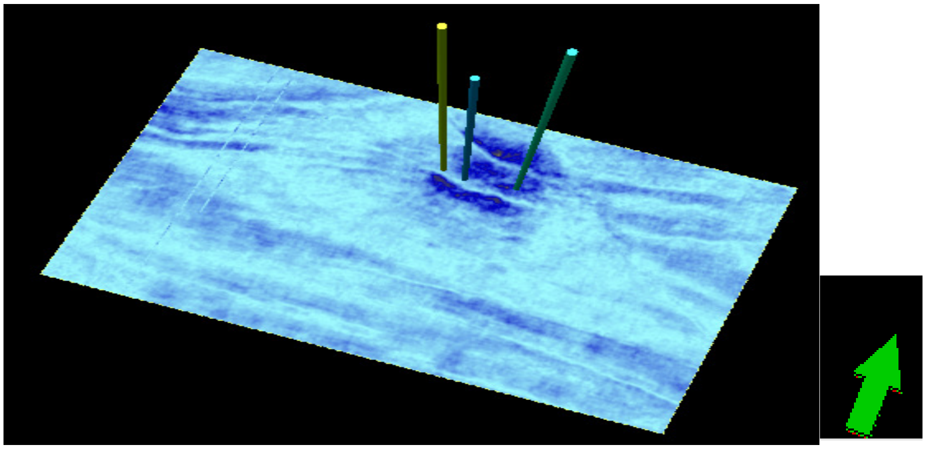

Figure 8: Sweetness attribute extracted on the surface

CONCLUSION

The result of the 3-D seismic structural and attribute analysis carried out in "Honynx" Field, revealed favorable petrophysical parameters with hydrocarbon saturation of 0.62. An anticlinal structure was also mapped that is conformable with amplitude from the attribute analysis. The result of this analysis has proved that the integration of attribute analysis with structural interpretation is a reliable and efficient way of carrying out hydrocarbon prospectivity evaluation of any oil field.

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