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The Use of Seismic Attributes and Well Logs in Delineating Kick Horizon; A Case Study of Nova Well, Niger Delta Basin, Nigeria

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ABSTRACT: Predrill pore pressure prediction of the NOVA well suggested that the drilling program was in agreement with available seismic surveys. However, a kick was encountered while during the well. The study was carried out to ascertain the cause of the kick horizon in the NOVA Well, using seismic attributes and well log. Eight stratigraphic horizons were characterized to describe the amplitude variations. The top and base of the kick horizon were picked and sculptured to create sub-volume maps.The results revealed that the kick horizon was a shaly unit. The kick horizon was far off bright amplitudes that could have delivered high pressure which could trigger a kick. Faulting, shallow water and gas flows have been suggested as possible causes of the kick. A kill weight mud should be factored into the drilling operations to produce hydrostatic pressure where the kick is entering the NOVA well in order to prevent a blow out.

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Keywords: Seismic attributes; kick, amplitudes; sculpture; well log; sub-volume.

Seismic attributes can be regarded as measures of seismic data which can be used to improve visualization and/or quantify features that are of interest when carrying out seismic interpretations (Chopra and Marfurt, 2006). They are tools for inferring geology from seismic reflection data (Banks, 2014). Seismic attributes can be used to identify structural features and hydrocarbons directly. They can also be used to interpret fluid type, reservoir quality and thickness. When combined with well logs, seismic attributes are powerful tools for predicting subsurface conditions in a wellbore.

Over the years, seismic attribute developments has recorded significant breakthroughs in seismic acquisition, reflector mapping, fault identification, bright spot identification, frequency loss, thin bed tuning, seismic Stratigraphy, geomorphology, stratigraphic and hydrocarbon anomalies (Chopra and Marfurt, 2006). Predrill pore pressure prediction of the NOVA well suggested that the drilling program was in agreement with available seismic surveys. However, a kick was experienced during the drilling of the well.

This work aims to use seismic attributes and well logs to ascertain the possible cause of the kick horizon in the NOVA well, Niger Delta.

MATERIALS AND METHODS

*Study Area:*The study area is located within the offshore Niger Delta (Figure 1). The Niger Delta is considered to be a prolific hydrocarbon province. The Niger Delta is located on the continental margin of southern Nigeria and it is bounded to the south by the Gulf of Guinea. The Delta formation began in individually separated and distinct minibasins ranging in tectonic configuration from extensional through translational to compressional toe-thrust regions (Damuth, 1994).The Tertiary Niger Delta consists of three lithostratigraphic sequence; the Akata, Agbada and Benin Formations. The Akata Formation consists of mainly shale which is said to be undercompacted in places and with traces of overpressured siltstones and sandstones (Avbovbo, 1978). The overlying Agbada Formation is a paralic sequence of alternating sandstones and shales. The Benin Formation overlies the Agbada Formation and is made up of mainly freshwater bearing fine grained sandstones with interbedded thin shales (Weber, 1971). Delteil *et al.*, 1974, Weber and Daukoru, 1975, have shown that overpressures are encountered in the Tertiary Niger Delta as a result of rapid sediment loading of the undercompacted shales of the Akata Formations by the sandy Agbada and Benin Formations. They also showed that the Akata shale is in contact with the

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sandy Paralic Agbada sediment in three different ways. Firstly, there is a vertical transition from continuous marine shales into Paralic sediments. Secondly, there are lateral facies transitions and interfingering of sand and clay, and thirdly, Akata shale is in many places in juxtaposition with Agbada paralic sediments across faults. In each of these cases, fluids expelled from the overpressured Akata shales may inflate (charge) the pressures in the adjacent sands.

Overpressure in sedimentary basins can be linked to increase in stress and in-situ fluid generating mechanisms. According to Chopra and Huffman, 2006; the ability of these processes to generate overpressures depends on the rocks, fluid properties of the sedimentary rocks and their rate of change under the normal range of basin conditions.

Undercompaction is the most well understood overpressure mechanism used to explain and quantify overpressures in Tertiary basins where rapid deposition and subsidence occur (Hubbert and Rubey, 1959), like the Niger Delta and Mississippi (Yassir and Addis, 2002).

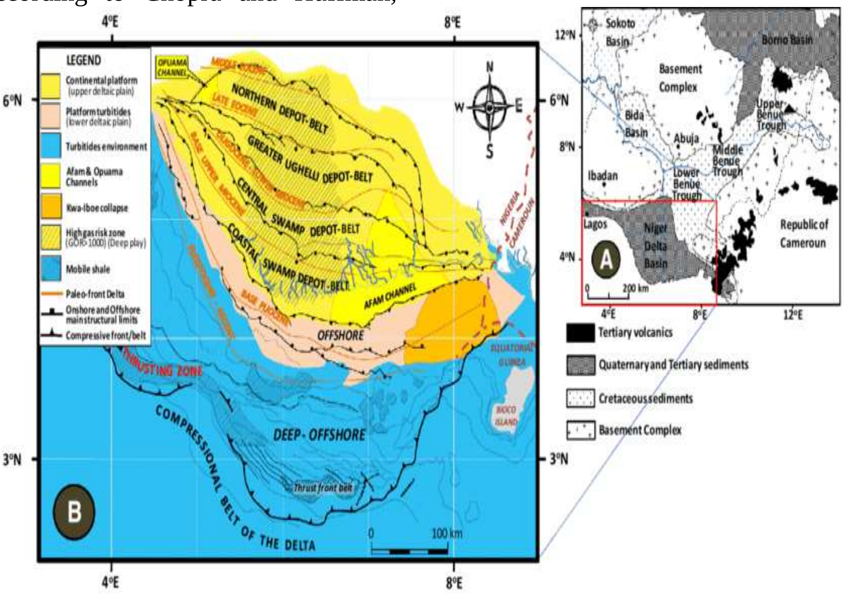

Fig 1: Geological Map of the Niger Delta (from Doust and Omatsola, 1990; Ebong *et al*. 2017)

Methodology: The shell proprietary interpretation software was employed for this research. The interpretations involved a high resolution 3D seismic data and a suite of well log comprising gamma ray, neutron log, density log, deep and shallow resistivity logs. The areal distributions of strong amplitude response which are indicative of gas bearing sands were mapped and to highlight these, a sub-volume was created. The seismic data was divided into various units and described according to the amplitude variations. The log was matched with the seismic data and the top and base of the kick unit were picked and the area penetrated by the well was sculptured. The resolution of the seismic was increased for clarity and the result was displayed with the well on map and volume windows.

RESULTS AND DISCUSSION

Amplitude Variations: Eight stratigraphic units (Figure 2) were identified based on the interpreted seismic section.

Unit A is characterized by low to moderate amplitudes, laterally continuous events, with high amplitude in places. It occurs between 1230ms and 1407ms, that is, 177ms thick, from the middle section to the right, the amplitudes become stronger on average.

Unit B: Unit B is characterized by isolated high amplitudes and low to moderate amplitudes. It occurs between 1407ms and 1548ms; it is141ms thick, on average.

Unit C: The thickness of this unit increased greatly from 141ms in Unit B to 502ms. It represents a wide hemipelagic drape. It is characterized by low amplitude continuous reflectors, isolated bright amplitudes in places. The top left section of this unit is more transparent and it is affected by faulting.

Unit D: occurs between 2130ms and 2159ms; it is 29ms thick and characterized by low, medium and high amplitudes which are fairly continuous.

Unit E: Unit E is characterized by low amplitudes, discontinuous and chaotic in places. It occurs between 2159ms and 2271ms; that is 112ms thick.

Unit F: Lies between 2271ms and 2292ms; it is 21ms thick and characterized by low amplitudes, discontinuous and chaotic in places.

Unit G: Unit G is 78ms thick and occurs between 2292ms and 2370ms. It is characterized by high amplitudes, continuous but interrupted by shale, low to moderate continuous amplitudes which increase towards the crest. The objective reservoir lies within this unit.

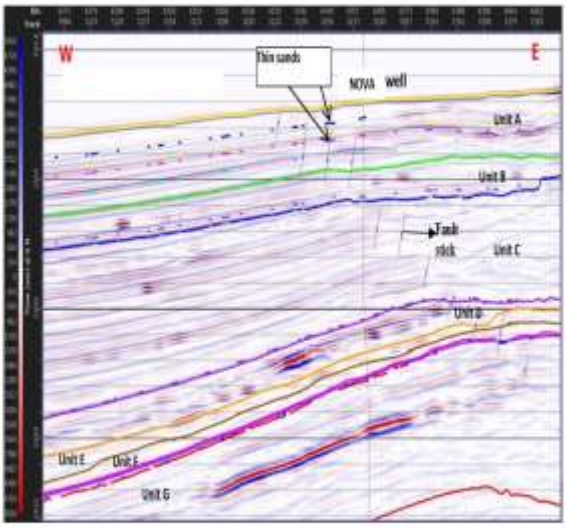

Fig2: Seismic dip section across NOVA well showing interpreted horizons

Sub-volume and amplitude anomaly investigation:
The areal distributions of strong amplitude responses which are indicative of gas bearing sand were mapped and to highlight these, a sub-volume was created. The kick horizon between units D and E (about 112ms thick) was further investigated to ascertain why the kick occurred. The top and base of this unit was then picked and the area penetrated by the well was sculptured (Figure 3).

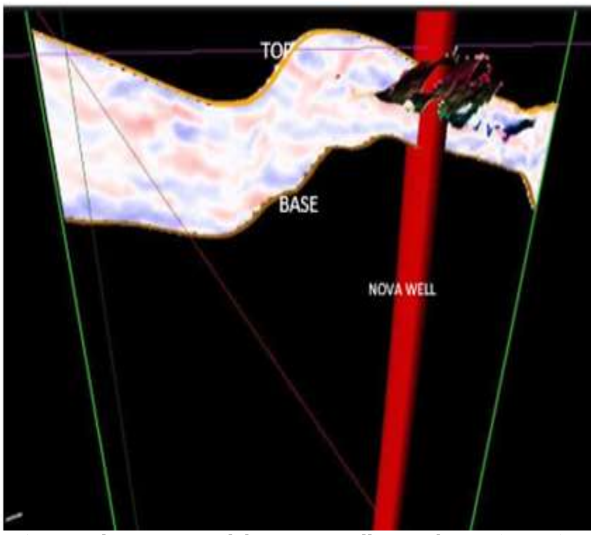

Fig 3: Sculpturing around the NOVA well using the top (orange) and base (brown) of kick unit as reference points

The resolution of the seismic was increased for clarity and the result was displayed with the well on a map (Figure 4) and volume windows (Figures 5 and 6). This confirmed that this unit does not correspond to large areas of high amplitudes. However, the volume and map views showed amplitude body of only limited lateral extent; that is isolated bright amplitudes were observed above the well path. To know the actual distance of these bright amplitudes from the well path, a sub-volume cube was created.

A traverse section A-A` (Figure 4) was taken along the well path and the bright amplitude above it to see if it has any potential risk. The bright amplitude (red cells) to the right in unit E is over 400m from the well path which is an acceptable distance because the well radius is 150m for typical offshore setting. A zoom in on unit E (Figure 7) indicate that it is weak and very far from any possible gas-filled sands.

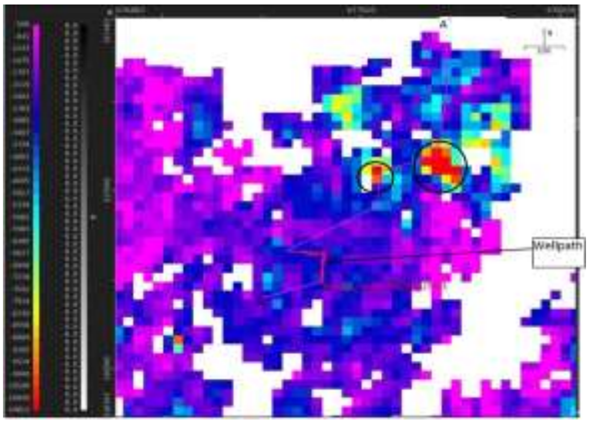

Fig4: Showing NOVA well and low amplitude around the well path. The bright amplitudes (red cells) are nowhere close to well path.

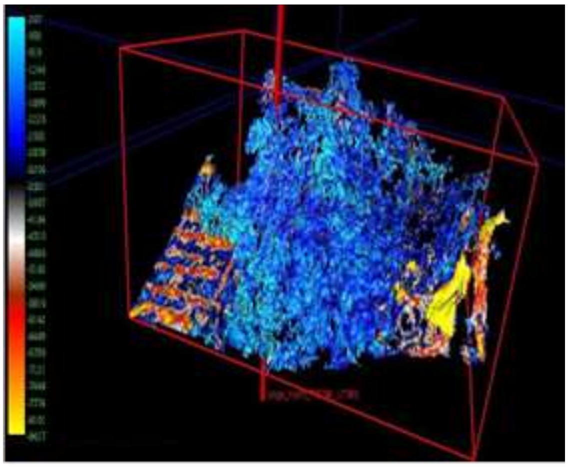

Fig 5: Side view of the volume cube indicating that the NOVA well only penetrated the low amplitudes (blue) and far from the bright amplitudes (red) within the kick unit.

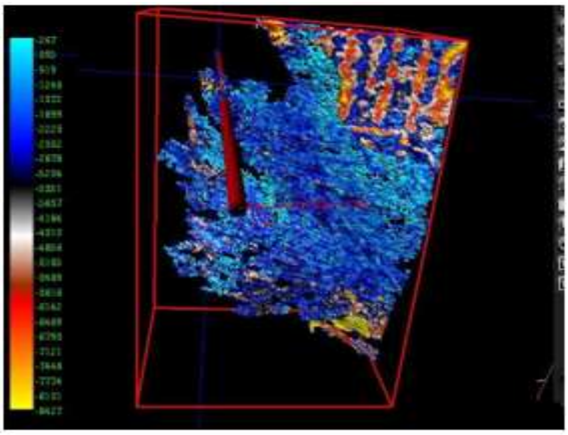

Fig 6: Top view of the volume cube confirming that the NOVA well only penetrated the low amplitudes

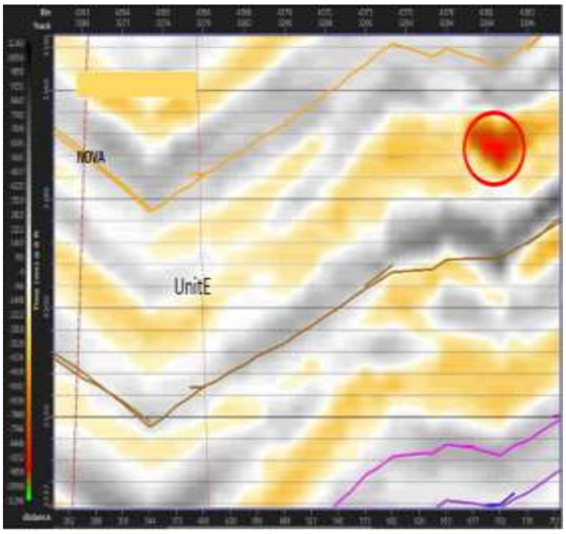

Fig 7: A zoom in on unit E showing the distance of the NOVA well from the localized bright amplitude (red). The distance is over 400m which is considered safe when compared with the 150m well radius required for safe drilling in a typical offshore setting.

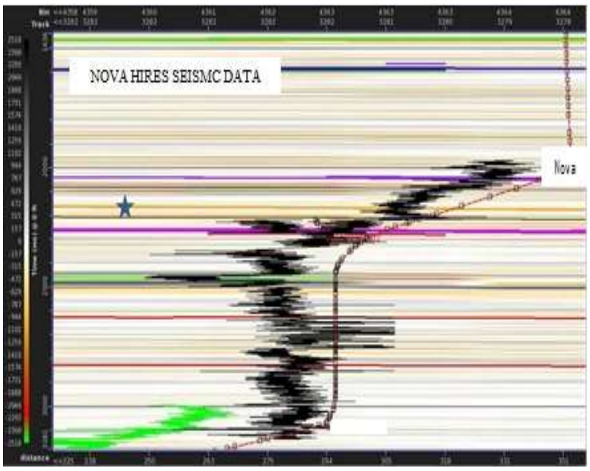

Fig 8*:* Seismic and well log showing the kick unit (marked with a star) corresponding to a shale

As shown on figure 8, when the seismic data and well log were matched, they were in agreement; the kick horizon is a shaly unit. The deflection of the log to the right indicates shale. In the absence of amplitude anomalies within this unit, so what caused the kick? Three possible reasons were identified. The first was shallow water flow.Since these shales are mobile and actively involved in the formation of shale diapirs, they must have been rapidly deposited and buried without having time to lose their fluids, especially their waters. During sediment loading/compaction, the fluids are neither lost nor dissipated; rather they are localized within the shales. The water in them acts as gas causing the high pressure that was delivered to the surface. Recall that the Akata shales are undercompacted and overpressured and as such, fluids which are released by these overpressured shales may charge the pressures in nearby isolated thin sands in units A and B. Shallow gas flow could have also caused the kick. The bit depth at point of influx is 5737ft, it is possible for the gas encountered at greater depths to get to the point of the kick because everywhere was opened (these sands were not cased at the time). Thus, the high pressure could have resulted from gas flows. Sandstones within the overpressured shales are stratigraphically divided into tiny, isolated and anomalously pressured zones. Faulting is another possible cause of the kick. The well is bounded by major faults (as shown by the numerous fault sticks in units' A-G on figure 2) and there is the possibility for faulting to deliver high pressures to shallow depths and isolated sands penetrated by faults may conduct pressures away from fault zones. Movement along faults and connection via very thin, sub-seismic sands are possible. It is therefore recommended that a kill weight mud should be factored into the drilling operations to produce hydrostatic pressure where the kick is entering the well.

Conclusion: The kick horizon is a shaly unit which does not correspond to areas with bright amplitudes. Amplitude anomaly is therefore not the cause of the kick. Shallow gas flow, shallow water flow and faulting have been suggested as the possible causes of the kick.

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