Application of Seismic Attribute Analysis to Establish Plio-Pleistocene Play in Island Area of KG-PG Basin, India

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Summary
KG-PG Basin evolved as an intracratonic to pericratonic rift basin which hosts commercial hydrocarbons from Permian to Recent sediments and offers a target for lucrative exploration. In KG Basin, the Deep offshore areas are principal producers from Plio-Pleistocene Sequences and numbers of wells had been drilled to target this play. As the Miocene and older Tertiary sediments were the principal plays in the island area and shallow offshore, wells drilled for them encountered Pliocene hydrocarbons in serendipity and so was not considered as a primary play. The present study integrates the occurrence of Pliocene play from deep offshore to Island area through Seismic attribute analysis. Different Seismic Attribute Viz. Sweetness, RMS Amplitude etc was carried out to bring out this understanding in the study area. Frequency study viz. spectral decomposition was also implemented in order to enhance geological understanding in the study area as it is related to the seismic resolution. Many geological features such as Channel-leave complex, Slope channels, Fan system and Mass Transport Complex (MTC) etc. were detected based on this analysis. Many abandoned channels of the age of Plio-Pleistocene were identified in the Island area of the KG-PG Basin and already established Shallow water & Deep-water channels were also detected based on the Seismic Attributes analysis.

Introduction
In most exploration and reservoir seismic surveys, the main objectives are, first, to correctly image the structure in time and depth and, second, to correctly characterize the amplitudes of the reflections. Assuming that the amplitudes are accurately rendered, a host of additional features can be derived and used in interpretation. Collectively, these features are referred to as seismic attributes.

The simplest attribute, and the one most widely used, is seismic amplitude, and it is usually reported as the maximum (positive or negative) amplitude value at each sample along a horizon picked from a 3D volume. It is fortunate that, in many cases, the amplitude of reflection corresponds directly to the reservoir depending upon the depth of occurrence. Attributes can be obtained from typical PSTM volumes, and these are the most common types. On the other hand, additional information can be obtained from attributes of the individual seismic traces prior to stacking, in a prestack analysis. The most common of these is the variation of amplitude with offset [or amplitude vs. offset (AVO)], which is often used as an indicator of fluid type. The interpretation of any attribute is nonunique, and calibration to well data is required to minimize the ambiguities present.

In the Study area the Seismic attributes Viz. RMS, Sweetness and Seismic Trace Attributes Viz. AVO, Intercept & Gradient analysis were carried out to understand the various Geological features and further calibrated with the drilled wells also.

Geology of the Area:
Extensive deltaic plain formed by two large east coast rivers, Krishna and Godavari in the state of Andhra Pradesh and the adjoining areas of Bay of Bengal in which these rivers discharge their water is known as Krishna Godavari Basin. The Krishna Godavari Basin is a proven petroliferous basin of continental margin located on the east coast of India Figure-1.

Figure-1: Location Map of KG Basin (DGH)
Its onland part covers an area of 15000 sq. km and the offshore part covers an area of 25,000 sq. km up to 1000 m isobath (DGH). The basin contains about 7-8 km thick sediments with several cycles
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of deposition, ranging in age from Late Carboniferous to Pleistocene. The Plio-Pleistocene sedimentation is dominated by slope shales and associated slope channel and fan systems in the shallow and Deep-water areas Figure-2.

Figure-2: Block Diagram Showing Deposition system of Plio-Pleistocene Sequences in shallow & deep-water area (DGH).

Sedimentation is locally controlled by accommodation developed by major gravitational growth faults. The Plio-Pleistocene sediments were deposited over the Regional Mio-Pliocene unconformity. This unconformity is extensive and can be tracked well from Island area to the deep-water blocks viz. KG-DWN-98/2 and beyond.

The sediments of Miocene and older ages eroded during this unconformity of Early Pliocene age, has probably been redeposit as the ubiquitous Mass Transport Complex in deep-water area. It is overlain by Godavari Clay of Pliocene-Recent age; a number of channel sand layers are encountered within it. In the KG Deep Offshore, the Late Pliocene- Early Pleistocene sequences overlying the regional Early Pliocene MTC pack are the established play for hydrocarbon accumulation.

The seismic signature corresponding to these slope channels are showing amplitude anomalies (Bright Spot) Figure-3, which are primarily targeted in shallow and deep-water areas.

Methodology:

In the present study we identify a seismic marker in between Early Pliocene top and Early Pleistocene-100, which corresponds to Zone-18 in Deep water, and named it as Zone-18 equivalent level. The Zone-18 Equivalent level is mapped regionally from KG deep offshore to island area.

The Regional section passing through Onland to deep-offshore area Figure-4 showing mapped levels i.e Mass Transport Complex, Early Plio top, Zone-18 Equivalent etc.

In shallow offshore area many drilled wells encountered hydrocarbon-bearing sands and are corresponding to mapped Zone-18 Equivalent level. In the island area also one of the well-A encountered hydrocarbon bearing sand corresponding to Zone -18 equivalent level in serendipity which gives us impetus to establish that play in island area.

Figure-4: Regional Section showing disposition of mapped levels

The arbitrary strike line passing through the Island area shows the deep Mio-Plio cuts available, which are the passage-ways for the entry of Pliocene Channel–Fan complex available in KG-shallow offshore and deep offshore area (Figure-5) these cuts are calibrated with present day river system.

Figure-3: Seismic Signature corresponding to Deep-water Slope Channels
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Figure-5: Arbitrary line showing Deep cuts at shallow level

Seismic attribute was attempted in the study area to bring out the sand dispersal pattern. Integrated RMS attribute map from Zone-18 Equivalent level to Pliocene Base bring out the sand dispersal pattern from island area to deep offshore area and is shown in Figure-6.

Figure-6: RMS Attribute showing Sand Dispersal of Plio-Pleistocene Sands from Island to Deep Water area.

The RMS attribute map depicts that established hydrocarbon pools in deep offshore area like GD, G1, Kanakadurga, Padmavathi, GS-29, G4 etc are corresponding to moderate to high amplitude anomalies exhibiting a channel-fan complex geometry. The integration of the RMS attribute map of Zone 18 equivalent in shallow offshore and island area with deep offshore brings out the extension of these deep-water channels right upto the mouth of present-day Vashishta and Vaineteyam (Figure-7) with some additional paleochannels in the Island area of KG-Basin.

Figure-7: Disposition of shallow & Deep-water Channel-Fan complex up to present day river mouth

As ‘Sweetness’ is an empirical attribute designed to identify ‘sweet spots’, places that are oil & gas prone. It is observed that in young clastic sedimentary basin, sweet spot imaged on seismic data tend to have strong amplitude anomaly and low frequencies. High sweetness values are those that are most likely indicate oil & gas. So, sweetness attribute was also attempted in zone of interest to understand the fluid discrimination.

In shallow offshore area, Zone 18 equivalent had been proven in wells- B, C & D which are falling in a channel and corresponding to moderate-high sweetness anomalies Figure-8.

Figure-8: Seismic Attribute (Sweetness) showing channels in Shallow water i.e is already established and proved

The Sweetness attribute map from Zone-18 to Pliocene base is very well calibrated with the drilled wells in shallow offshore and deep offshore
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areas and sands are corresponding to moderate-high amplitude anomalies. In island area well-A is falling in moderate amplitude Figure-9 on the periphery of high amplitude anomaly and it produced hydrocarbon @ 40199 m3/d from this anomaly (area ~ 0.085km).

Figure-9: Drilled Well-A showing Amplitude Anomaly corresponding to encountered Zone-18 Equivalent Sand

Processed Log of well-A showing the presence of Hydrocarbon bearing sand corresponding to Zone-18 Equivalent level. The presence of commercial hydrocarbon in well-A at Plio-Pleistocene sequence has given the impetus to establish similar play in the island area of KG Basin. The RMS & Sweetness attribute map shows the presence of two different paleo channels in Island area of KG Basin and one channel at the mouth of Vaineteyam river in Kesnapalli West area marked by discrete sand bodies in each channel represented as high amplitude anomalies shown in Figure-10.

Figure-10: Sweetness attribute showing Unexplored paleo channels identified in Island area of KG Basin

Seismic Trace Analysis:

Direct determination of lithology and pore-fluid content from seismic data has been the goal of geophysicists for a long time. One specific phenomenon that has been extensively utilized is the occurrence of a Bright Spot or Amplitude Anomaly in a true amplitude processed seismic section. Geophysicists in the 1980’s started looking at pre-stack seismic data, and found that amplitude change with offset could be modeled. Also, AVO is a good tool to minimize risk so for that gather analysis was carried out at the drilled well-A position and at the identified channels to minimize the risk. Synthetic seismogram of well-A (Figure-11) depicts that the sands are low impedance sands and corresponding to trough.

Figure-11: Synthetic Seismogram of Well –A

Gradient analysis at well-A @ 846 m corresponding to gas bearing zone shows AVO class-III anomaly Figure-12. AVO class-III sand has low impedance than the encasing medium and exhibited as classic Bright spots sands shows as amplitude anomaly in stacked section. Which is clearly brought out in seismic attributes P*G (product of intercept and gradient) attribute which is often referred as hydrocarbon indicator also generated at drilled Well-A. In low impedance gas sands encased in shale are having a large negative intercept and large negative gradient, then the reflection from outside the target zone. Thus P*G is a good indicator for class-III type gas sands shows a large positive value, it indicates the presence of gas in a sand shale alternation sequence. P*G is often used to verify Bright Spots.

Figure-12: Dilled Well-A showing AVO Class-III anomaly corresponding to Hydrocarbon Bearing Sand.
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Gradient analysis also carried out at the position of identified paleo-channels. All identified channels depict AVO-Class-III anomaly corresponding to target zone as shown in Figure-13.

Figure-13: Identified Paleo-Channel showing AVO Class-III anomaly

Conclusion:

KG basin has already been proven as a prolific HC producer where hydrocarbon has been located in various plays ranging from Permian to Pleistocene. The present study integrates the onland and offshore area to bring out the new play of Plio-Pleistocene age in Island area of KG Basin, which is already established in Shallow & Deep offshore areas. It may open up a new frontier in Island area of KG Basin for lucrative exploration and exploitation.

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