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# Integrated well log and 3-D seismic data interpretation for the Kakinada area of KG – PG offshore basin

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***Abstract:*** *In this paper Structural and stratigraphic mapping within the Krishna Godavari offshore Basin in central part of the eastern passive continental margin of India was commonly carried out using traditional field geological methods. The main objective of the study is to get the general geological setup of the area, i.e. Stratigraphy, structural setup, presence of hydrocarbon, petroleum system, and reservoir features like porosity, permeability, reservoir extent etc and a practical experience in the workstation, for this, data like various logs (GR, Resistivity, Density, Neutron and Sonic logs), seismic data have been used. In order to do this work Geophysically, it has been done by using Open-Works suite of software, a proprietary of Landmark. In the present work, various horizons were identified using well logs. 3-D seismic data were also used where the seismic cross section were developed. Next, the horizons were all traced in those three dimensional volumes and in the same way the faults were also traced. Six major horizons were identified with well log data, and five fault are identified they are F1, F2, F3, F4 and F5. The F1 running from south to north and F2, F3, F4, F5 all are from east to west. Finally an interpretation were done and reported.*

***Keywords:*** *Krishna Godavari basin, Structuralsetup, Stratigraphy, Open- works, Seismic, Sonic.*

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## I. Introduction

In seismic interpretation quantitative 3-D characterization of sedimentary bodies is vital for a better understanding of the distribution and flow paths of gas and fluids (such as hydrocarbons or water). Sediment bodies are the result of depositional processes that are complex and variable with time and place. It is possible to study them in outcrops or wells, whereby direct access to the rocks is gained, but these methods usually do not provide full 3-D information, and, therefore, the reconstruction of the sedimentary processes that shaped them is difficult. However, new techniques of studying outcrops and shallow subsurface deposits (3-D seismic, ground-penetrating radar, borehole imaging, and digital geological methods) offer a much more complete characterization of the geometries and intrinsic properties of sedimentary deposits [1]. The resultant seismic volume presents a less ambiguous image of subsurface than the data from the Two- Dimensional survey. Such data reveals unique depositional systems. Our study includes detailed investigation of the rock cuttings and data inputs from lab. The digital results are then used to build a deterministic model that can be analyzed with appropriate visualization technology. Such models provide new and important insights into the geological heterogeneity of sediment bodies, on their genesis and on the subsequent diagenetic changes. They are particularly powerful when combined with process-based models. The insights that are thus gained represent predicting tools in the development of hydrocarbon reservoirs and aquifers. Mainly when there is a carbonate deposits as a major deposits we need to have a clear knowledge of interested area [2]. In this project even though the major part of the basin consist of carbonate reservoir, where my study area consist of east coast of Krishna and Godavari basin – Permian to Recent age syn-rift clastic form as a major reservoir[3]. In this project data inputs are taken from 3D seismic data and well log data like Resistivity, Density, Neutron porosity, Sonic, and Gamma ray log. Basically there are two wells in the area they are well A, B, C and D. All the wells are drilled more than 4500mts. Firstly all the horizons have been identified and correlated with data from well logs and seismic. Then the horizons where traced slice by slice in the in-line and in the cross-line direction, this is done so that the horizon can be identified by the profile of any direction. In the same way faults present in that area where also traced. For the further clear interpretation results from lab was also considered and interpretation was made.

## II. Materials And Methods

### Seisworks Used For Mapping Correlation

SeisWorks 3D software provides innovative 3D viewing and interpretation capabilities and easy-to-use interpretation productivity tools to support and enhance horizon and fault interpretation. It is the industry standard for 3D seismic data analysis and interpretation. With SeisWorks 3D software, interpreters can work with a 2D project and multiple 3D projects concurrently for great interpretation flexibility [4]. But in this project has been taken a part of Kakinada area of KG offshore basin. In this seismic section six major horizon and four faults only mapped. Basically there are two wells in this section; they are A and B. This seismic section has NE-SW direction.

**Horizon – 1**

This horizon has been tracked using seiswork S/W application of M/S land mark suite in every 25 inlines and cross lines and later interpolated and mapped at 50ms contour interval. RMS amplitude was extracted for -40 to 100ms from this horizon there is no anomaly and channel features. The age of this horizon (sea bed) is given by Palaeocene top as shown in fig 1.

**Horizon – 2**

This horizon has been tracked using seiswork S/W application of M/S land mark suite in every 25 inlines and cross lines and later interpolated and mapped at 60ms contour interval. RMS amplitude was extracted for -150 to 100ms from this horizon also no variation which has brought of some anomaly like channel features. The age of this horizon is given by upper cretaceous top as shown in fig 2.

**Horizon – 3**

This horizon has been tracked using seiswork S/W application of M/S land mark suite in every 25 inlines and cross lines and later interpolated and mapped at 100ms contour interval. RMS amplitude was extracted for -150 to 100ms from this horizon which has brought of some anomaly like channel features. The age of this horizon is given by upper Jurassic lower to cretaceous top as shown in fig 3.

**Horizon – 4**

This horizon has been tracked using seiswork S/W application of M/S land mark suite in every 25 inlines and cross lines and later interpolated and mapped at 50ms contour interval. RMS amplitude was extracted for -150 to 100ms from this horizon which has brought of some anomaly like channel features. The age of this horizon is given by upper Jurassic to lower cretaceous top as shown in fig 4.

**Horizon – 5**

This horizon has been tracked using seiswork S/W application of M/S land mark suite in every 25 inlines and cross lines and later interpolated and mapped at 50ms contour interval. RMS amplitude was extracted for -100 to 100 and -150 to 100ms from this horizon which has brought of some anomaly like channel features. The age of this horizon is given by Oligocene to upper Jurassic lower cretaceous top as shown in fig 5.

**Horizon – 6**

This horizon has been tracked using seiswork and S/W application of M/S land mark suite in every 25 inlines and cross lines and later interpolated and mapped at 100ms contour interval. RMS amplitude was extracted for -150 to 100ms and -300 to 200 from this horizon which has brought of some anomaly like channel features. It is also called basement. The age of this horizon is given by Oligocene to upper Jurassic lower cretaceous top as shown in fig 6.

**Fault recognition and mapping**

When an interpreter works with 3D data after having previously mapped 2D are the same prospect, the most striking difference between maps is commonly increased fault detail in the 3D map. Any horizontal section alignment indicates the strike of the features. If there is a significant angle between structural strike and fault strike, event will terminate. If structural strike and fault are parallel, or almost so, the event will not terminate but will parallel the faults. The difficulty of seeing faults on a time slice when they parallel structural strike is over come using the attribute coherence. Because an alignment of event terminates on a horizontal section indicates. The strike of a fault, the picking of a fault on horizontal section provides a contour on the fault plane. Thus picking a fault on a succession of suitability spaced horizontal sections contour an easy approach to fault plane mapping. Today interactive work station help in the coordinated use of vertical and horizontal sections by providing the capability of cross posting. When a fault is picked on a vertical section, its intersection will appear an intersecting horizontal section.

In this section there are five faults, they are F1, F2, F3, F4 and F5. Basically these faults are continuously coming. Above that reason this is called host and graben. These are the faults generated in different time interval and different formation like gollapalli and basement as shown in fig 7.

In basement and gollapalli formation some faults are generated. Firstly the fauts trends are made in 3D data seismic section (Inline) and these faults trends followed by time interval and mapped in map view section. Thse are the fault trends in E-W direction and it is continuously coming because it is called horst and graben as shown in fig 8 & 9.

**Well log correlation**

The correlation curves of the natural gamma ray logs, neutron logs, resistivity logs, density logs and sonic logs of longitudinal waves from measured in boreholes are presented in each column curves representing the same methods at the same scale are differentiated by colour. Given the wells A, B, C and D are differentiated by gamma ray, neutron, resistivity, density and sonic logs.

**Upper cretaceous top**

The cretaceous top marked by different log curves. The well A at 1038m level the gamma ray curves increasing and neutron curves decreasing. The well B at 1085m level the gamma ray curves increasing resistivity curves decreasing. The well C 930m level gamma ray curves increasing and neutron curves decreasing. Above these reason it is presume that upper cretaceous formation.

**Lower cretaceous top**

The lower cretaceous top marked by different log curves. The well A at 1410m level the gamma ray curves decreasing, resistivity curves increasing and neutron curves also increasing. The well B at 1498m level the gamma ray curves decreasing resistivity curves increasing and neutron curves also increasing at the same time well C 1306m level gamma ray curves decreasing resistivity increasing and neutron curves also increasing. Above these reason it is presume that lower cretaceous top.

**Upper Jurassic to lower cretaceous top**

The upper Jurassic to lower cretaceous top marked by different log curves. The well A at 2565m level the gamma ray curves suddenly increasing resistivity curves decreasing and neutron curves also decreasing. The well B at 2648m level the gamma ray curves increasing resistivity curves decreasing and neutron curves also decreasing at the same time well C 2470m level gamma ray curves increasing resistivity curves decreasing and neutron also decreasing. Above these reason it is presume that upper Jurassic to lower cretaceous top.

**Permo triassic top**

The permo triassic top marked by different log curves, the well A at 3300m levels the gamma ray curves increasing resistivity decreasing and neutron curves also decreasing. The well B at 3265m level the gamma ray curves increasing resistivity curves decreasing and neutron curves also decreasing at the same time well C 3010m level gamma ray curves increasing resistivity decreasing and neutron curves also decreasing. Above these reason it is presume that upper cretaceous top as shown in fig 10.

## III. Results And Discussion

**Reservoir facies characterization**

**Well A**

This well has been correlated using openworks and stratworks application of land mark suite in different lithology and later major stratigraphic formation correlated with well B and well C. In this different lithologies are there like limestone, sandstone, shale and clay. The major formations are Palaeocene & younger, Upper Cretaceous, Lower Cretaceous, Upper Jurassic to Lower Cretaceous and basement. Only three major formations have been taken for sand-shale ratio. These are the Early Cretaceous (1410m),Golapalli(2565m) and basement(4726) and which has brought of some lithology like sand, shale and clay. The total depth of this well is 3785m.

**Well B**

This well has been correlated using openworks and stratworks application of land mark suite in different lithology and later major stratigraphic formation correlated with well A and well C. In this well different lithology are there like limestone, sandstone, shale and clay. The major formations are Palaeocene & younger, Upper Cretaceous, Lower Cretaceous, Upper Jurassic to Lower Cretaceous and basement. Only three major formations have been taken for sand-shale ratio. These are the Early Cretaceous (1495m), Golapalli(2648m) and basement(4670) and which has brought of some lithology like sand, shale and clay. The total depth of this well is 4290m.

**Well C**

This well has been correlated using openworks and stratworks application of land mark suite in different lithology and later major stratigraphic formation correlated with well C and well B. In this well different lithology are there like limestone, sandstone, shale and clay. The major formations are Palaeocene & younger, Upper Cretaceous, Lower Cretaceous, Upper Jurassic to Lower Cretaceous and basement. Only three major formations have been taken for sand-shale ratio. These are the Early Cretaceous (1320m), Golapalli(2470m) and basement(3400) and which has brought of some lithology like sand, shale and clay. The total depth of this well is 3400m.

**Well D**

This well has been correlated using openworks and stratworks application of land mark suite in different lithology and later major stratigraphic formation correlated with well C and well B. In this well different lithology are there like limestone, sandstone, shale and clay. The major formations are Palaeocene & younger, Upper Cretaceous, Lower Cretaceous, Upper Jurassic to Lower Cretaceous and basement. Only three major formations have been taken for sand-shale ratio. These are the Early Cretaceous (1271m), Golapalli(2118m) and basement(4826) and which has brought of some lithology like sand, shale and clay. The total depth of this well is 3680m.

**Isopach map of early cretaceous formation**

The Isopach map has been created by manually. Thickness of the isopach map of early cretaceous formation well A 1155m, well B 1155m, well C 1164m and well D 847m. The contour interval of this formation 100m and this formation consist of different lithology are there like clay, sandstone, limestone and shale. In this formation dominantly accommodated shale. Well A nearer to the well B and the well C & D away from these two wells. The structure contour slightly closed as shown in fig 11.

**Isopach map of gollapalli formation**

The thickness of the isopach map of golapalli formation of well A 2161m, well B 2022m, well C 930m and well D 2708m. The contour interval of this formation 100m and this formation consist of different lithology are there like clay, sandstone, limestone shale, siltstone and minor coal (in well C) . In this formation dominantly accommodated shale ad sandstone. Well A nearer to the well B and the well C & D away from these two wells. The map of structure contour closed and the map clearly depicts the contour trending east west direction as shown in fig 12.

**Sand isolith map of early cretaceous formation**

The thickness of the sand isolith map of early cretaceous formation of well A 62m, well B 14m, well C 115m and well D 19m. The contour interval of this formation 10m and this formation consist of different lithology are there like clay, sandstone, limestone and shale. In this formation dominantly accommodated shale. Well A nearer to the well B and the well C & D away from these two wells. The map of structure contour closed and the map clearly depicts the contour trending east west direction as shown in fig 13.

**Sand isolith map of golapalli formation**

The thickness of the sand isolith map of golapalli formation of well A 135m, well B 416m, well C 338m and well D 470m. The contour interval of this formation 50m and this formation consist of different lithology are there like clay, sandstone, limestone shale, siltstone and minor coal (in well C). In this formation dominantly accommodated shale ad sandstone. Well A nearer to the well B and the well C & D away from these two wells. The map of structure contour closed and the map clearly depicts the contour trending east west direction as shown in fig 14.

**Sand- shale ratio map of early cretaceous formation**

The thickness of the sand/shale map of early cretaceous formation of well A 0.10m, well B 0.01m, well C 0.12m and well D 0.02m. The contour interval of this formation 0.02m and this formation only considered that sand and shale. In this formation thickness of sand for well A 62m and shale 1093m. In well B sand 14m and 1139m, in well C for sand 115m and shale 1149m and in well D sand 19m and shale 828m. This map of structure contour closed and the map clearly depicts the contour trending east west direction as shown in fig 15.

**Sand- shale ratio map of gollapalli formation**

The thickness of the sand/shale map of early cretaceous formation of well A 0.14m, well B 0.40m, well C 0.36m and well D 0.36m. The contour interval of this formation 0.05 m and this formation only considered that sand and shale. In this formation thickness of sand for well A 135m and shale 985m. In well B sand 416m and shale 1553m, in well C for sand 338m and shale 918m and in well D sand 470m and shale 1134m. This map of structure contour closed and the map clearly depicts the contour trending east west direction as shown in fig 16. The hydrocarbon accumulation is in the uppermost part of the upper Jurassic to lower cretaceous age. This hydrocarbon bearing layer is present in wells A and B. The well C and D are dry wells. This sequence thins down and pinches out towards north.The Paleocene clastic sequence have been observed in the southern part of the study area. As per laboratory studies carried out by ONGC on source rock data, the Paleocene coal-shale sequence within this southern low has acted as a source rock for generation of hydrocarbon. Hydrocarbon migration from the source has taken place along the N-S trending faults and entrapment of hydrocarbon had taken place within the fault bounded nosal structures available on the pathway of migration. The E-W trending fault towards the north of the study area appears to be a sealing fault, as hydrocarbon accumulation is restricted to the structures south of this fault. All the hydrocarbon bearing wells A and B are situated to the south of this fault while the well C & D, drilled in the northern fault block has proved to be devoid of hydrocarbon.

## IV. Conclusion

Based on the interpretation of the well log curves of the four wells A, B, D, and C. six major top of horizons where identified. They are paleaocene and younger, upper cretaceous, lower cretaceous, upper Jurassic and lower cretaceous, permo triassic (basement).These horizons consist of different lithology. Namely permo tiassic is made up of sandstone, shale, siltstone and coal, upper Jurassic to lower cretaceous consist of sandstone, shale with minor coal, lower cretaceous consists mainly of limestone. Upper cretaceous consist of Limestone, sandstone, clay and shale. Paleaocene & younger consists of clastic sediments. All through the deposition the structure of the basin is maintained. The map clearly depicts the southward slope of the area with time contours trending in general east-west direction. The most widespread unconformity between pleaocene and Tertiary is prevalent both in the onshore and in the offshore areas. A number of nosal features are observed in horizon 5&6 the area bounded by faults F1, F2 and F3; and also at area bounded by faults F4 and F5.These are the places where further wells can be drilled for exploration. An attempt to identify the reservoir facies analysis and porosity distribution where made with the help of the basis of porosity data from electro logs and Formation Evaluation Reports and core Analysis of drilled wells.

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