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Paleo-Depositional Systems in the Krishna Godavari Basin, East Coast of India

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Abstract: Krishna-Godavari (K-G) basin is a continental passive marginperi-cratonic basin. It is located along the east coast of India. The basin got initiated through rift/syn-rift tectonics between Permo-Triassic to early Cretaceous periods. It consists of the deltaic plains of the Krishna and Godavari Rivers and the inter-deltaic regions. The areal extent of on land part is about 15,000 sq. km whereas the offshore area covers about 215000 sq. km up to 1,000 m isobath. The basin contains about 5 km thick sediments with several cycles of deposition, ranging in age from late Carboniferous to Pleistocene. The major geomorphologic units of the K-G basin are upland plains, coastal plains, Recent flood plain, and delta plain. Exploration for hydrocarbons in this basin was started in 1958 conducting geological mapping. Geophysical surveys using gravity and magnetic methods were started in 1964, and the seismic surveys were carried out from 1972 in the basin to identify the favourable sites of hydrocarbon accumulation. During the last four decades, 647 deep wells were drilled in different parts of the basin for exploration of oil and gas and their production activities of which 465 well are on landwhich include 85 development wells. More than 225 prospects were drilled out of which 83 are hydrocarbon bearing.

Cretaceous sediments having a thickness of about 6 km are known in the peri-cratonic K-G basin. Archaean basement consisting of khondalites, charnockites and some sedimentary rocks occur towards north and west of the basin. Lower Gondwana rocks overlie the basement and are exposed in a limited areas adjoining the Godavari Graben. There are several horsts and grabens in the basin. Many growth faults are also known here. The Pranhita Godavari Graben is a linear intra-cratonic rift that is in the south-central part of Peninsular India. The stratigraphic column of the basin includes older Talchir Formation of Permo-Carboniferous overlain by Barakar formations which in turn underlie the Chintalapudi sandstone of Permian age. The tectonic history of the K-G basin comprises of the Rift Stage, Syn-rift Stage, Drift Stage, and Late Drift Stage. A Petroleum System can be summarized as an independent stratigraphic compartment within which three primary requisites for hydrocarbon accumulation viz., the source, reservoir, and cap rocks occur. The basin has good hydrocarbon potential, and expletory efforts to locate oil and gas pools through seismic-stratigraphic analysis may enhance the discovery rate.

Keywords:*K-G basin, Peri-cratonic basin, rift, syn-rift, Gondwana, Godavari Graben, Pranhita Godavari Graben, Talchir, Barakars, oil and Gas Pools and Seismic-Stratigraphic Analysis*

1. Introduction

The Krishna-Godavari basin, a peri-cratonic basin, is located along the East Coast of the Indian peninsula. It includes the deltaic plains of the Krishna and Godavari rivers and the inter-deltaic regions. Geographically, the basin lies between Kakinada in the northeast and Ongole in the southwest. Achaean crystalline basement and Upper Cretaceous sedimentary outcrops demarcate the northwest basin margin. The basin extends southeast into the deep water of the Bay of Bengal. A significant part of the onshore basin area is covered by Quaternary alluvium.

The areal extent of on land part of the basin is about 15,000 sq. km. whereas up to1,000 m isobath, the areal extent is about 25,000 sq. km which further opens into deep waters of Bay of Bengal.

Exploration for hydrocarbons has started with geological mapping at the basin margin areas in 1958. Apart from geological mapping, geo-morphological studies and detailed paleontological and palynological studies were also carried out to establish the clear startigraphic boundaries.

Geophysical surveys such as gravity and magnetic surveys were started in 1964, and the seismic surveys were carried out in the basin from 1972. The integrated subsurface data interpretation resulted in identification of few structural anomalies in Narasapur-Razole area in 1976. Accordingly,Oil and5Natural Gas Commission (ONGC) prioritized their drilling schedule in the basin and hence drilling was commenced in the basin at Narasapur. This first well drilled in the basin in 1978 has established gas accumulation in the structure and found associated with abnormal formation pressures. At present, Krishna-Godavari basin is the unique one having established oil and gas reservoirs in all formations ranging from Pliocene to Permian.

During these 38 years of exploration and production activity, so far 647 deep wells were drilled in different parts of the basin, of which 465 are on land, which include 85 development wells. More than 225 prospects were drilled, of which, 83 were hydrocarbon bearing (Figure1).

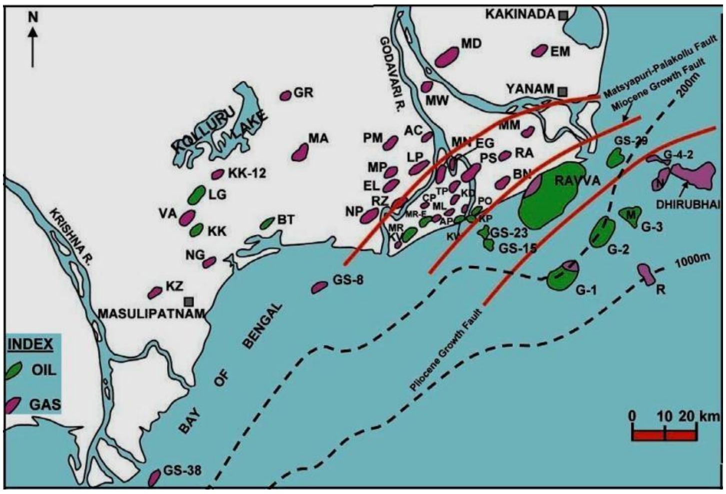

Figure 1.Map ofOil-Gas Fields ofK-G Basin

Geological Set Up

The Indian Peninsula was separated from the Gondwanaland during 141 Ma. At the time of break-up, it was positioned at 500south latitudes. The Indian plate started moving with newly generated oceanic crust from Cretaceous period. The early Triassic to Jurassic section is represented by red clays. Once oceanic crust has been formed on either side of the Indian plate, 900 east ridgeand Carlsberg ridge in the west have become trajectories for the movement of the Indian plate. The eastern passive continental margin of India has subjected to tectonic readjustments of continental blocks with the denser oceanic crust which has resulted into subsidence of crustal blocks. During this phase, the Eastern Ghats trend (NE-SW) was reactivated and resulted into NE-SW aligned horsts and grabens superimposing the pre-existing trend. Due to this passive margin subsidence, southeasterly slope has developed which facilitated NW-SE drainage with sedimentation. More than 3000m of Cretaceous sediments are known in the peri-cratonic Krishna-Godavari basin (Rao, 2001). The Cretaceous fluvio-marine sediments occur as outcrops at NW basin margin areas of K-G basin. Seismic stratigraphy has become important in K-G basin to understand the elements of petroleum system for hydrocarbon exploration point of view. Seismic stratigraphy is a technique for interpreting geological information based on seismic data. Together with its offspring sequence stratigraphy, it is acknowledged as being among the most significant development in the geology (Emery and Myers, 1996. Sequence stratigraphy provides a chronostratigraphic framework for the correlation and mapping of sedimentary facies and for stratigraphic prediction. It has remarkable potential to decipher the geological documentation of local to global changes and to improve the predictive aspect of economic exploration and production of hydrocarbons. These are termed as Upper Gondwana rocks and are represented by lower coarser clastic sediments (Gollapalli sandstones), middle argillaceous (Raghavpuram sandstones) and Upper arenaceous sequences (Tirupati sandstones). This thick pile of sediments has resulted in to an iso-static rise at the basin margin area, due to which lower Gondwana sediments exposed as outcrops. Southeastern limit of Chintalapudisandstone formation at Paloncha neck demarcate the areas of iso-static rise towards northwestern parts of the graben and passive margin subsidence towards southeastern parts. The erosion of lower Gondwana sediments over the horst, and sometimes its absence over the basement ridges and at some other places,result in variation in thickness in the lows.

Towards north and west, the basin is limited by Archaean Basement consisting of gneisses, khondalites,charnokitesand some type of soils. Lower Gondwana (upper Permian to lower Triassic) rocks overlie the basement and are exposed in a limited area adjoining Godavari graben. Here, they are known as

Chintalapudi sandstones which were deposited under continental or freshwater environment. Unconformably overlying the Lower Gondwana or the basement, the Upper Gondwana (Jurassic to Cretaceous) rocks are exposed in three main patches located around Eluru,Budavada-Vemavaram andKandukuru. These sediments have also been encountered in several shallow wells drilled. They differ in facies from one area to another with depositional environmentvarying from continental through transitional to marine.

The Pranhita Godavari Graben is a linear intra-cratonic rift located in the south-central part of Peninsular India. It occupies a NW-SW trending linear tract extending from north of Chandrapur in Maharastra to south of Aswaraopeta in Andhra Pradesh. Crystalline Archean basement and sediments of Puranas group of Proterozoic age mark the margins of the graben towards NE and SE. These upper Gondwana sediments are overlain by Infra-trappeans. This contact is neither exposed nor penetrated by any shallow well. A maximum of 75 meters of thickness has been encountered in Dudukuru shallow well, where three Trap (Deccan basalts) flows have been recognized. These basalt flows are separated by inter-trappean beds. These beds are nearly 100m thick and seems to thin out towards southeast and might have been deposited in estuarine conditions. Though Eocene sediments are not exposed, about 75m thick section was encountered in Duddukuru well which overlie the basalts non-conformably. Rajahmundry formations of Mio-Pliocene occur in small hillocks in these areas. They gradually overlap all the older formations and finally rest over the basement at some places. The Holocene sediments of fluvial and deltaic origin cover the Rajahmundry formation (Figure 2).

Structure And Tectonics

The Krishna Godavari basin occupies a strategic position as it coincides with the triple junction of the diverging India, Australia, and Antarctica plates (Murthy et al., 1980). Though the southeastern continuity of Pranhita Godavari graben could not be established with certainty, the recent marine geophysical surveys have established with fairness the continuity of Pranhita Godavari graben up to Ocean Continent Boundary(OCB).

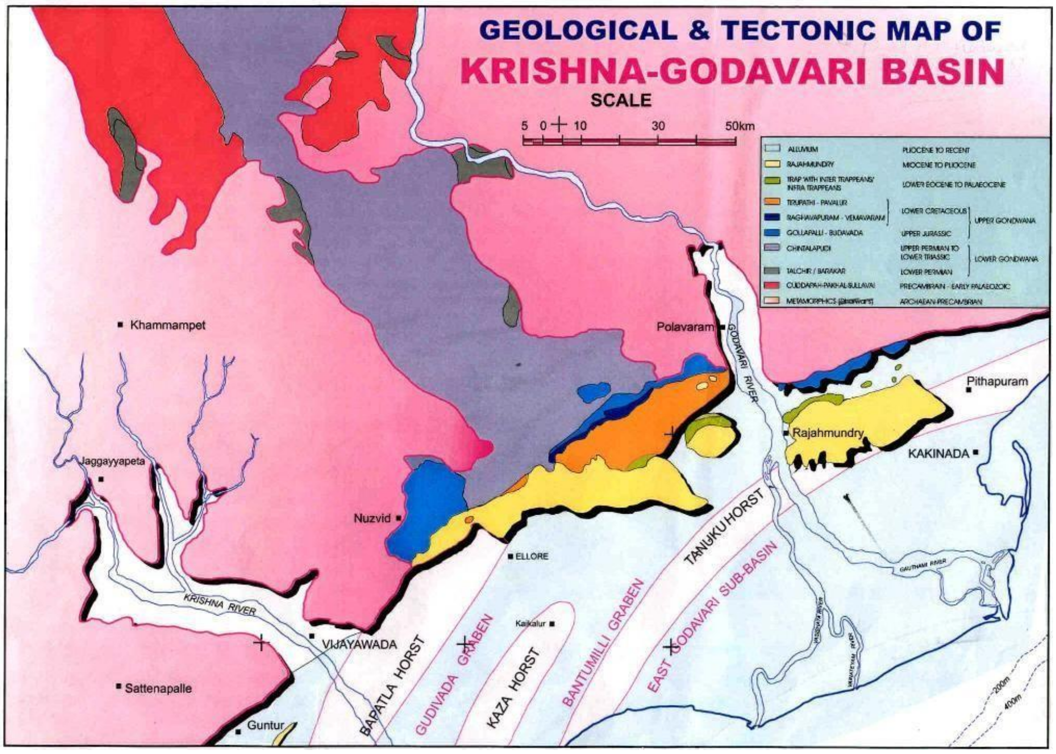

Figure 2.Geological & Tectonic Map-Krishna Godavari Basin

Krishna-Godavari basin is a Continental peri-cratonic basin of passive margin. The basin came into existence following rifting along eastern continental margin of Indian craton in the early Mesozoic period. The down to the basement faults which define the series of horsts and grabens cascading down towards the ocean are aligned NE-SW along Precambrian Eastern Ghats trend. While the onshore basin is characterized by NE-SW ridges and depressions, the offshore basin is divided essentially into three segments by these two NW-SE cross trends. The OCB located at the foot of the continental slope of this region, appears to be the seaward limit of these two cross trends.

The intense magnetic anomaly located off Machilipatnam is related to a hotspot at the time of initial rift of the Indian plate. The Chintalapudi cross-trend appear to be older than other structural features of K-G basin. Another linear trend at Yanam called Pithpuram cross-trend suggests a linear basement ridge with an average depth of 3 km, and it is fault controlled. Pranhita Godavari graben is now known to continue up toOCB between these two cross trends with axis located off Amalapuram at right angles to coastline.

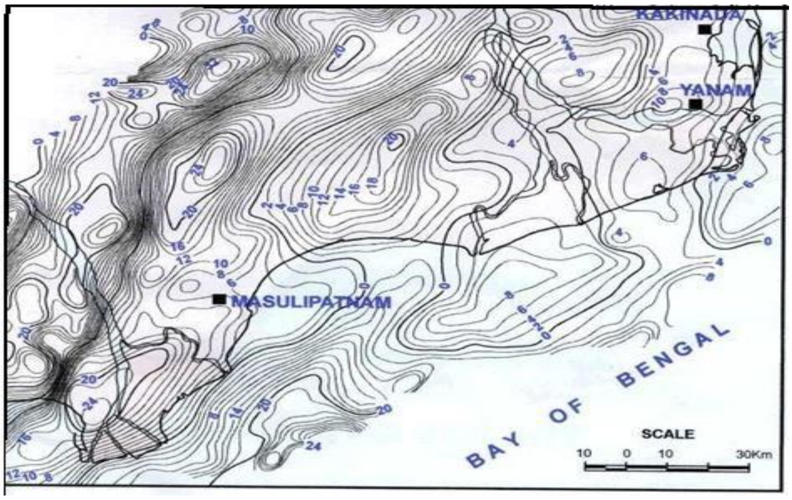

Figure 3. Residual Bouguer Gravity Map: K-G Basin

The Bouguer gravity map of the area also clearly brought out the PG graben and its structural limits, however in the coastal on land area the gravity lows and highs are aligned in NE-SW trend (Figure 3).

They are named Krishna, West Godavari and East Godavari Sub Basins differentiated by Bapatla and Tanuku Horsts. Further the west Godavari sub-Basin is divided into Gudivada Graben and Bantumilli graben by Kaza-Kaikaluru horst. Few small lows are aligned in NW-SE trend right upto shallow offshore area (Figures4A& 4B). The geological history comprises of the following stages:

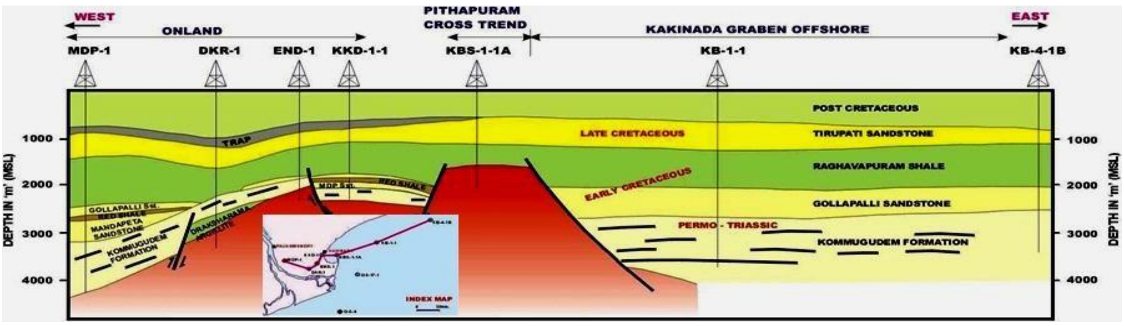

Figure 4A

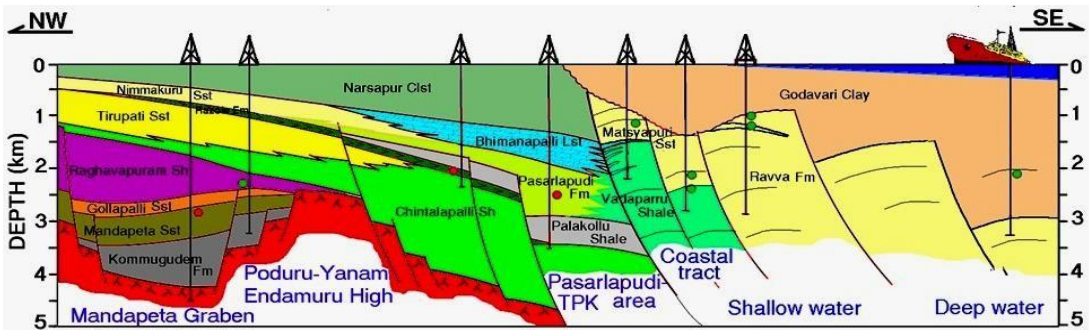

Figure 4B

Figures 4A & 4B. Geological Sections

Rift Stage:

The basin got initiated through rift/syn-rift tectonics between Permo-Triassic to Early Cretaceous and is essentially characterized by lagoonal or fluvial or occasionally brackish water sediments. The northeastern part of the present on land basin was part of an intra- cratonic rift set up till Jurassic that constituted the southeastern extension of NW-SE trending continental rift valley slopping northward. The basin has been initiated through rifting during Permo-Triassic period.

Syn-rift Stage:

In the early stage ofsyn-rift sediments were deposited during early subsidence by tectonic fault systems. Basin subsidence continued along basement bound fault system accommodating syn-rift sediments of late Jurassic to early Cretaceous.

Drift Stage:

Rift to drift transition is marked by a southerly/southeasterly tilt of the basin leading to widespread marine transgression during Cretaceous and deposition of marine shale sequence followed by onset of overall regressive phase during Late Cretaceous, represented by a deltaic sequence comprising Tirupati sandstone with dominant arenaceous facies. During Mastrichtian-Danian, the basin experienced major volcanic activity having span of 5.5 million years.

Late Drift Stage:

Initial soft collision between the Indian and Eurasian plates and initiation of Matsyapuri-Palakollu fault appears to have greatly influenced the Paleogene and younger tectonic regiment and the consequent sedimentation pattern.

Sedimentation

The inter-cratonictectoni-sedimentation cycle of fluvio-lacustrine sediment (Kommuguden formation) of the Permian age and the dominant sandstone of Mandapeta formation of the Triassic age constitutes a southern extension of Gondwana sedimentation (Pranhita-Godavari) in K-G basin. The basin experienced a major hiatus (late Triassic to late Jurassic), corresponding to the Yanshanian Orogenic Moment-1 (Ravishankar et al., 2005) prior to the breakup of the Indo-Australia-Antarctica Gondwanaland.The restricted marine environment, shallow bathymetry, very slow rate of sedimentation and the nearness to the provenance resulted in the depositionof High Gamma-High Resistivity Shale (HG-HR) sequence (Man Mohan and Rao, 1998 and 2002).The sedimentary thickness is of more than 6 km. It is likely composed of primarily clastic facies of shale, fine sandstone, siltstone, and clay with thin bands of carbonates. Mesozoic deposition during Permo-Triassic-Jurassic time was primarily non-marine and associated with horst and graben features. The rift phase continued till Lower Cretaceous time and the end of this phase was marked by a transition from non-marine to marine environment during Mid-Upper Cretaceous. The early syn-rift sediments (Gollapalli equivalents during Tithonian- Borremian) were deposited during early extensional subsidence accentuated by the earlier basement rifted fault system. The post-rift deposition was primarily shallow marine to marine characterized by prograding clastic sequences. The growth faults and associated rollover conditions featured the deposition. Post-Miocene tectonism resulted in the formation of smaller but sharp, as well as flat and large, anticlinal structures within the Tertiary sequences in the deep waters. Paleocene sequences onlap onto the paleo-highs of Cretaceous and Miocene onto Oligocene at the shelf break. Major slope failures act as the primary source of turbidite accumulations. Most channels are filled with coarse sediments. Since Proto Godavari is flowing through the rift graben with sediments, The Neogene sediments in the Basin are of second order with finer clastic sediments, favourable situation for both generation and accumulation of hydrocarbons.

The Paleozoic sedimentary exposures towards NW of Chandrapur and SE of Aswaraopeta demarcate the known limits of the mega graben. However,the graben in all possibility extends below the Deccan syncline. During passive margin phase, the K-G basin experienced widespread extrusion of volcanic basalt (Keller et al., 2008) during late Maastrichtian to early Palaeocene during the northward drifting of the Indian plate over the Reunion hotspot (Curray and Munasinghe, 1991). The drainage reorganization has fed enormous sediment inputs resulting in further outbuilding of delta progradation further southeast into coastal and offshore area accompanied with fast syn-sedimentation. During late Oligocene the K-G basin witnessed a higher magnitude of sea level drop (Raju et al., 1994 and 2005) exhibiting hiatus of the order 7.5 ma 9The Deccan basalt exposures at Rajahmundry and its presence below the coastal Tertiary sedimentary basin is known due to presence of Permian sediments at Mandapeta evidenced by deep drilling in Krishna–Godavari basin for hydrocarbon exploration.

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Towards the end of Cretaceous, due to southeasterly tilt of the Basin developed well defined basin margin-shelf-slope system. During that period, a major part of the study area was in the slope regime resulting in deposition of thick basinal shales. However, during Paleocene, with further fall in sea level, shelf edge steadily prograded towards southeast exposing a substantial part of the shelf area. South-easterly flowing streams constituted a network of delta system which prograded basin ward. Moderately thick limestones, sandstones and minor shales are the litho-types in the shelf regime during this period, which grade into thick monotonous shales. Deposition of thick sand bodies in the slope regime due to turbidity currents is envisaged in the area between wells Bhimamanapalli and Amalapuram area. During Eocene, position of shelf edge had shifted marginally towards south-east. The sandstone, limestone and claystone gradually grade into thick, monotonous shales in the deeper part.

The isopach maps prepared for Upper Cretaceous, Palaeocene and Eocene sequences indicate single depositional lobe with migration to northeast located at present Godavari River mouth. The iso- map of Miocene and above section clearly brought out to lobe sone against Godavari and other at present Krishna Mouth. It can be fairly concluded that during late Eocene or Oligocene due to some tectonic uplift in mid land area the proto-Godavari might have bifurcated into Krishna and Godavari River systems. Further, the prograding sediment into sea at Krishna mouth area suggests lesser syn-sedimentary subsidence of the area.

Stratigraphy Of The K-G Basin

The stratigraphic column of the basin includes older Talcher Formation of Permo-Carboniferous overlain by Barakars which in turn underlie the Chintalapudi sandstone of Permian. A red coloured sandstone sequence separates these fluvial pre- Cretaceous sequence and deltaic/marine Cretaceous and younger sections.The Late Cretaceous-Early Palaeocene basaltslithologically distinguishes the Tertiaries and Mesozoics in the basin. A thick carbonate section of middle Eocene further differentiates the stratigraphic column. In the northwestern and western margins of the K-G basin, outcrops of Archaean crystallinerocks and sediments ranging in age from late Permian to Pliocene are present. However, major part of the basin is covered by alluvium or sea. The outcrop and sub-outcrop lithologic information has been gathered from many wells drilled in the shelf area and on land. The lithofacies variations of a given geological time, that is, proximal arenaceous and basinalargillaceous sequences can clearly be identifiable in the basin. All these lithofacies variations are studied in space and time and a comprehensive rock stratigraphic nomenclature was suggested as shown in Figure5.

Depositional Environment

Four distinct depositional systems have been recognized in the K-G basin which are 1. The Godavari Delta System, 2. Masulipatnam Self Slope System, 3. Nizampatnam Shelf Slope Systems and 4. Krshna Delta system.

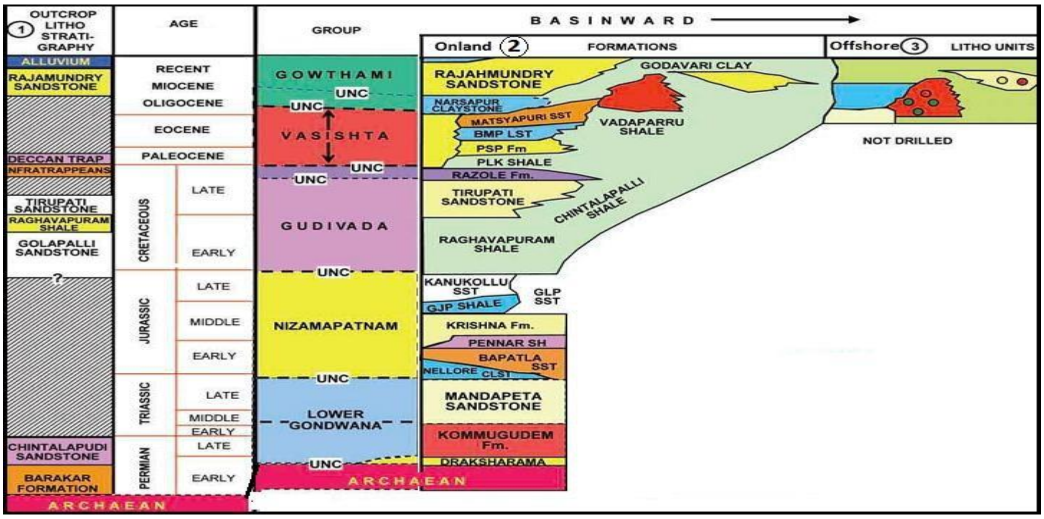

Figure 5. Stratigraphic Nomenclature: Krishna-Godavari Basin

Deltas And Hydrocarbon Exploration

The concept of exploration of unconventional hydrocarbons in India had been pioneered way back in early nineties (Padhy, 1989; Padhy and Naik, 1991; Mishra, 2008; Kumar, 2013). A Petroleum System can be summarized as an independent stratigraphic compartment within which the three primary requisites for hydrocarbon accumulation, that is, source, reservoir and cap rocks can occur. Other two important factors to find hydrocarbon accumulations are protection of organic matter and its maturation. Migration and entrapment are also requisites to find good oil and gas fields.Deltas are favourable locale to have all these requisites and hence places preferred oil and gas search. Further, for maturation of organic matter to generate oil and gas sufficient pressure and temperature conditions are also needed. Geologically deltas overlying paleo-rift basins provide such conditions and found best sites for hydrocarbon exploration. Krishna-Godavari basin is ideally located for oil and gas search, like Niger delta in West Africa.

In subsurface identification of paleo-deltas can also be primary target for exploration of oil and gas. Using the initial exploration data an attempt was made to map such paleo-delta positions in subsurface of Krishna Godavari basin.

Deltas and Oil exploration: delta front and pro delta areas are depositional sites of good quantity of organic matter both terrestrial and marine. If syn-sedimentary subsidence is there such organic matter may reach reducing conditions early (below photic zone) there by protected from oxidation. If such delta front areas are in case located over continental crust and/or paleo rift basin, more heat flow can make early maturation of source beds.

Geothermal gradient map prepared using well data in the basin showed higher than normal trend at shallow offshore area off Godavari mouth (Ravva area) which can possibly be due to overlying of the sediments over Oceanic crust. Another higher trend is noticed in KazaKaikaluru area in West Godavari sub-Basin. Gamma-ray spectroscopic logs of these wells indicated higher thorium content and hence the anomaly may be due to radioactive mineralization.

The continued subsidence couple with progradation of deltas may add sufficient over burden which will help maturation as well as expulsion of hydrocarbons from source beds that means facilitates primary migration of hydrocarbons. Land ward continuity of these prograding sequences may help connectivity in sandstone beds which will form good carrier beds for secondary migration. Syn-sedimentary growth faults in delta front areas may form good lateral seals helping to form major hydrocarbon pools. The proportionate mix of both argillaceous and arenaceous mix of sediments will improve the both local and regional cap rock facies which will help in forming strati-structural accumulations.Hence Krishna Godavari Basin is ideally located for hydrocarbon exploration and results will support the concept.

However, in case the syn-sedimentary subsidence is faster than normal compaction time the bottom section may become under-compacted and become abnormally pressured with in such formations. This aspect is also seen in sedimentation of Godavari basin. The upper Cretaceous section lying below Basalts is found to be abnormally pressured, leading to drilling complications while drilling during initial stages of exploration in the basin. With addition of more data the reasons for generation of abnormal pressures wereanalysed.

Keeping in view the operational efficiency while drilling through abnormal pressure sequences, different pressure gradient profile maps for various depth ranges were prepared (Fig.6). It has helped in

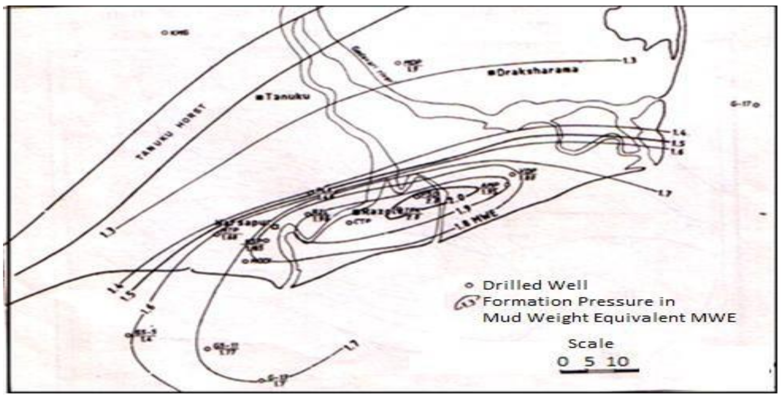

Figure 6. High Pressure Gradient Map at 3,500 m Level: K- G Basin

predrilling intelligentsia regarding occurrence of formation pressures and take precautionary measures while drilling (Rao and Mani, 1993).Generally, the reservoirs associated with abnormal pressures are found to be relatively thin, limited areal extent and gas bearing. The deepest flowing reservoir is at 4,444m level at Chintalapalli. These reservoirs when put on production are found to be fast depleting. Drilling also will be costlier due to depth and abnormal pressures. Hence economic viability to develop such zones found to be limited. So since late nineteen nineties it was decided to drill wells up to moderate formation pressure depths in the basin.

In Krishna Godavari Basin four operating Petroleum Systems are identified and they are stratigraphically classified as Pre-Cretaceous, Cretaceous, Paleogene and Neogene systems.

Kommugudem-Mandapeta-Red Bed System:

The Barakar Coal Shale Sequence of pre-Cretaceous is a matured source facies sequence, type of organic matter is mainly Type-III. Possibly due to which the hydrocarbon generation is mainly gas prone. Reservoir rocks are of Mandapeta formation with good porosity and permeability. The entrapment style is of Strati-structural nature. The overlying red-bed sequence is acting as regional cap facies for this oldest operating system in the Basin. Mandapeta gas field and its adjacent fields are producing gas from the system.

Raghavapuram-Gollapalli-Razole System:

The lower Cretaceous Raghavapuram Shales and Upper Cretaceous Chintalapalli Clay stone are matured source facies and matured during Eocene. The available overburden pressure is facilitated for primary migration of hydrocarbons for the source rocks. Since organic matter is of land derived it seems to be gas prone. Deccan Basalts of Early Palaeocene act as regional cap facies. Due to under-compaction of sediments in SE part of East Godavari sub-basin the reservoir sequences are associated with abnormal formation pressures. Entrapment style is of mainly startigraphic nature. The first hydrocarbon strikes in the basin like Narasapur, RazoleChintalapalli are within this system.

Palakollu-Pasarlapudi-Bhimanapalli System:

In this system, PalaeoceneVadaparru shale is a matured source facies. Sometimes Carbonate section of Bhimanapalli Limestone with organic facies may act as source facies and generation of oil is a possibility within this system. The top of Eocene Carbonate section is also acting as regional cap facies in southeast part of east Godavari sub-basin. Palaeocene sandstone facies within the carbonate sequence are reservoir beds in the system. Reservoir sandstone are poorly sorted angular grained with bioturbations. Limestones exhibit vugs. Entrapment Conditions include strati-structural in nature. Sands are thin and multi-layered, clastic wedges, fault closures, roll-over structures etc. Some of the oil and gas fields of the system include Bhimanapalli, ElamanchiliTatipaka, Pasarlapudi, Kadali and Manepalli. Mori prospect is oil producer. These oil fields including GS-38 in offshore area indicate good hydrocarbon potential in the Eocene sequence.

Type III source rock with some marine input. The source rock maturity varies between 0.7% -0.8% and subsidence modelling suggests generation of hydrocarbon from the Early Miocene to present day. Migration and filling of the Middle Miocene reservoirs occurred during Late Miocene as this provides a seal to the main field. Trapping must have occurred against older faults or stratigraphic traps that were in place prior to Early Pliocene faulting. The sandstone reservoirs were deposited in a wave dominated deltaic environment where relative sea-level fluctuations through time resulted in fluvial tosub-marine slope sedimentation. Hydrocarbon reservoirs are in the fluvial channels, beach ridges, barriers, and upper shore face environments.

The high-stand thick shale sequences of Lower late Miocene and Pliocene-Pleistocene packages form the most effective top and lateral seal for Middle Miocene reservoirs and Late Miocene gas caps. The commercial hydrocarbon accumulation in Ravva field is well known. The prospects GS-38, G-1 and G-2 are also hydrocarbon bearing in Mio-Pliocene strata.The hydrocarbon reserves sequence wise are: 330 in pre-Cretaceous, 230 in Cretaceous, 300 in Paleogene and 270 in Neogene reservoirs. Geographically, 575 MMT are in on land area and 555MMT in shallow offshore area. So far, nearly 495MMT of in place reserves were established out of 1,130 MMT of resources estimated. This indicates basin might have reached mature stage of exploration.

2. Conclusions

The subsurface data reveal the presence of a thick sediment fill in the basin and the extension of the northwest-southeast–trending Pranahita-Godavari graben underneath the northeast-southwest–trending Krishna-Godavari basin between two major cross-trends. The continuation of the basin is visualized to reach the Ocean Continent Boundary(OCB), located in the deep-water area of the basin. The southeastern part of the basin is a major Tertiary depositional centre because of a series of down-to-the-basin faulting during the early Palaeocene. Because of change in the gradient, major delta progradation is not seen in the area during the Palaeocene and early Eocene. The sediments filled rapidly in the lows has facilitated smooth progradation of the delta toward the southeast since the middle Eocene.

The positions of shelf edges through the geological ages have been marked. The Neogene depositional system has bifurcated into two separate depocenters in the basin since the Miocene. The litho-facies variations within marked sequences were discussed in detail and a litho-stratigraphic nomenclature is proposed for the entire sedimentary column of the basin. In the basin, good source rocks are identified in the sequence ranging from Permian-Carboniferous to Lower Miocene. The envisaged depositional patterns of the basin through geological ages help to identify locales of good reservoir facies in the vicinity of source facies. The basin has good hydrocarbon potential and exploratory efforts to locate oil and gas pools through seismic-stratigraphic analysis may enhance the discovery rate.

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3. References

[1] Curray, J and Munasinghe, 1989. Time of intraplate deformation, North Indian Ocean: Earth Planet Sci. Lett. Vol, 94, pp. 71-77.

[2] Emery, D., and Myers, K.J., 1996: Sequence Stratigraphy. Blackwell Science ltd. Pp. 45.

[3] Keller, G., Adate, T., Gardin, S., Bartolini, A and Baipai, S., 2008: Main Deccan Volcanism phase ends near the K-T boundary: Evidence from the Krishna-Godavari Basin, SE India. Earth Planet. Sci. Lett. Vol. 268, pp. 293-311.

[4] Kumar, A., 2013: Shale gas: Indian Scenario and Indian perspective, Proceedings, 3rd, Seminar on Petroliferous Basins of India: Implementation Strategy for PP-2030, ONGC Bulletin, Vol, 48, pp. 77-102.

[5] Man Mohan, M and Rao, M.R.R., 2002: Origin and Occurrence of Lower Cretaceous High Gamma-High Resistivity (Raghavapuram) Shale Sequence, K-G Basin, Journal of Geological Society of India, Sept. 2002.

[6] Man Mohan, M., and Rao, M.R.R., 1998: An Integrated Analysis of Lower Cretaceous High Gamma-High Resistivity Shale, K-G Basin, SRBC, E&D Group, Geology Section, K-G Project, ONGC, Rajahmundry (Unpublished).

[7] Mishra, R., 2008: Shale Gas Exploration in India: Opportunities and Challenges, Abstract Vololume, GEO India Expo. XXXI, Noida, New Delhi.

[8] Murthy, K.V.S., and Ramakrishna, M., 1980: Structure and Tectonics of Godavari- Krishna coastal sedimentary basins. Bulletin of Oil and Gas Corporation, Vol, 17, pp. 147-158.

[9] Padhy, P.K. and Naik, G.C., 1991: A feasibility study of oil shale exploration in India and its environmental impact, International Conference on "Mineral Development and Environment", Abstract Volume, p.8, Indian School of Mines, Dhanbad.

[10] Padhy, P.K., 1989: A note on feasibility study of oil shale exploration in India, EBG, ONGC Nazira (Unpublished Report).

[11] Raju, D.S.N., Bhatia, M.L., Ali, Q.A., Dave, A., Chatterjee, T.K., Mishra, P.K., Jaiprakash, B.C., Prasad, B. and Saxena, R.K., 1994: Sea-level changes, anoxic conditions, and their relation to hydrocarbon occurrences in K-G and Cauveru Basins, KDMIPE Report No. GRI. 03. R. 309, ONGE, Dehradun.

[12] Raju, D.S.N., James Peter, Ravishankar and Gopendra Kumar., 2005: An overview of Litho-Bio- Chrono Sequence Stratigraphy and sea-level changes in Indian sedimentary basins, APG Special Publication, allied Printers, Dehradun, pp. 210.

[13] Rao, G.N. 2001. Sedimentation, Stratigraphy and Petroleum Potential of Krishna-Godavari Basin,Bull. AAPG, Vol., 85, pp1623-1643.

[14] Rao, G.N. and Mani, K.S., 1993: A study on generation of abnormal pressures in Krishna-Godavari basin, India. Indian Journal of Petroleum Geology, Vol. 2, No. 1, pp.20-30.

[15] Ravishankar, Gopindra Kumar and Maithy, P.K., 2005: Palaeogeographic evolution of India and its implication for hydrocarbon: An approach, 1st APG Conference Exhibition in Stragic Challenges and Paradigm Shift in Hydrocarbon Exploration with Respect to Frontier Basins, Mussorrie, pp.23-42.