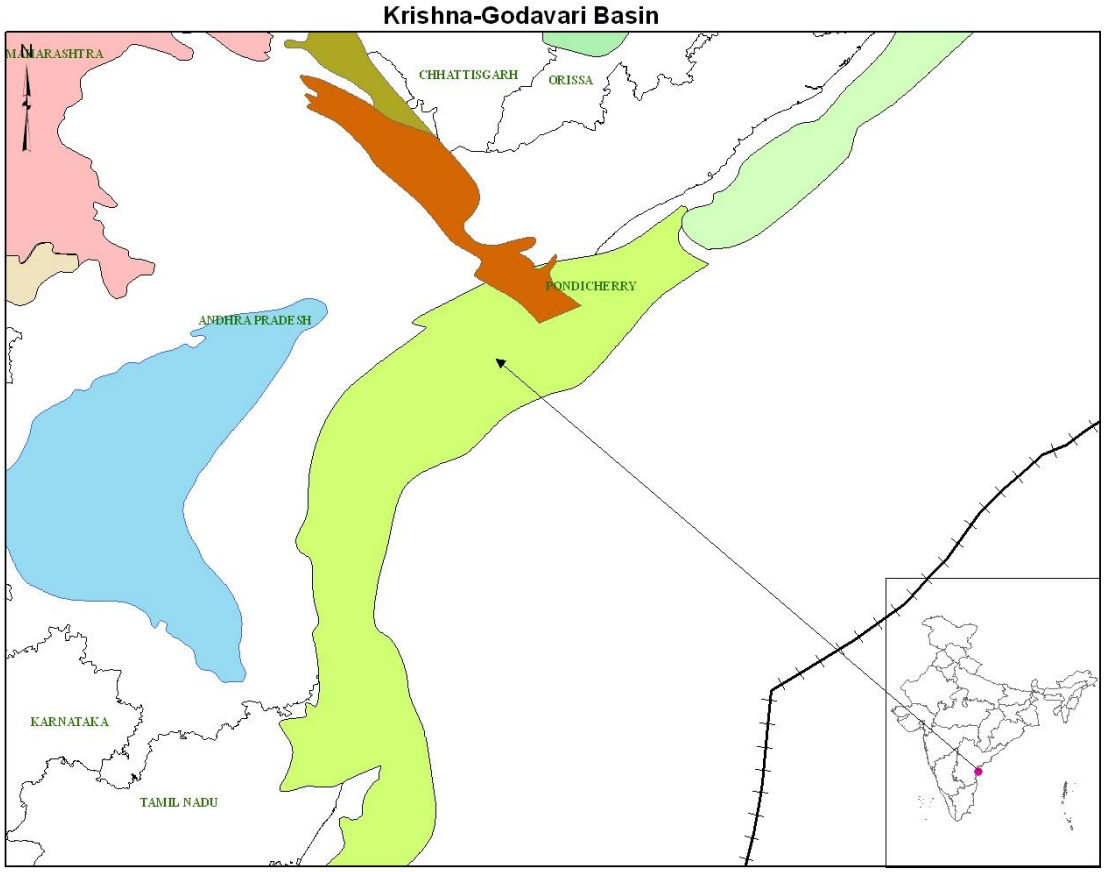
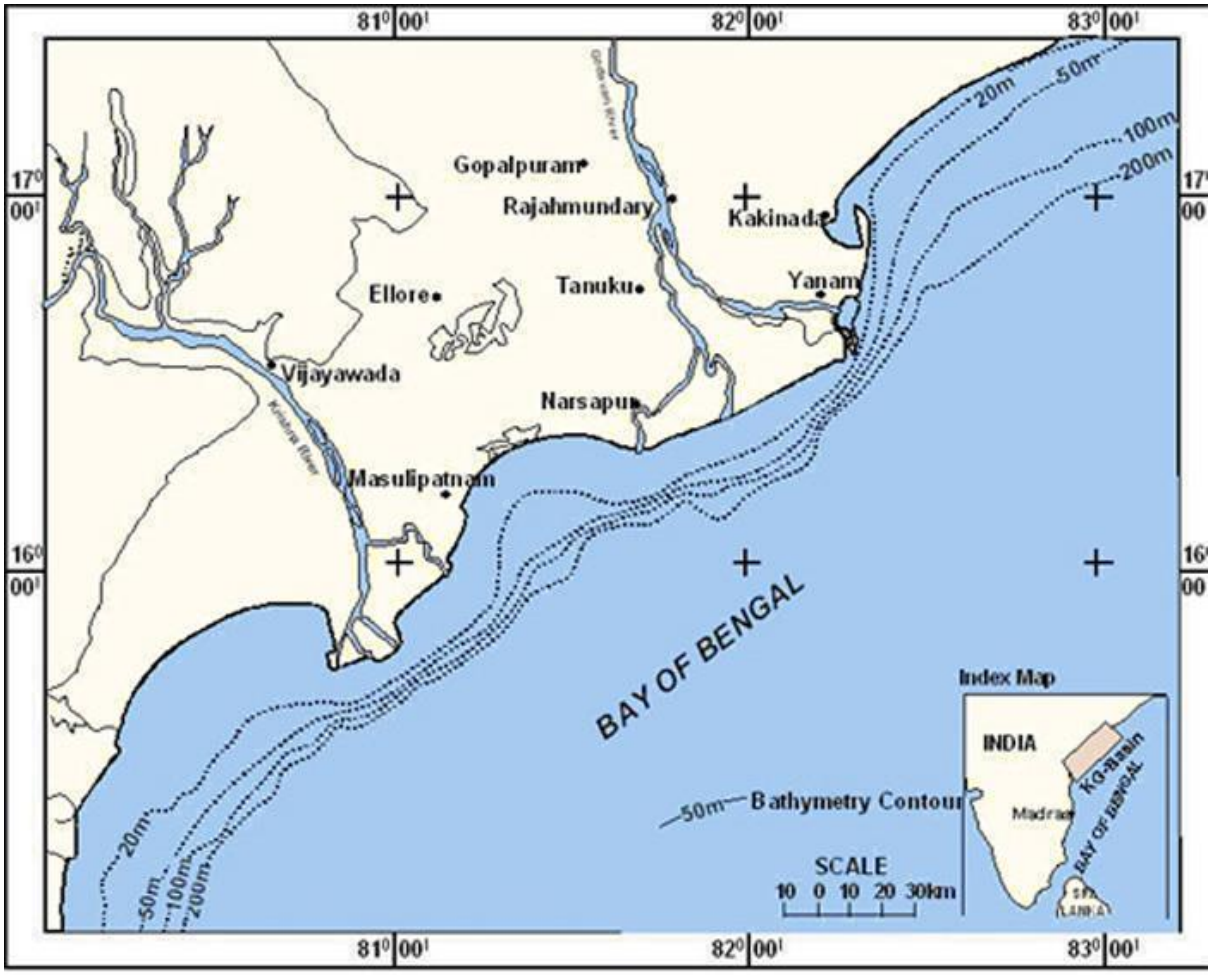
Basin Introduction :



.

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 .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. The basin contains about 5 km thick sediments with several cycles of deposition, ranging in age from Late Carboniferous to Pleistocene.

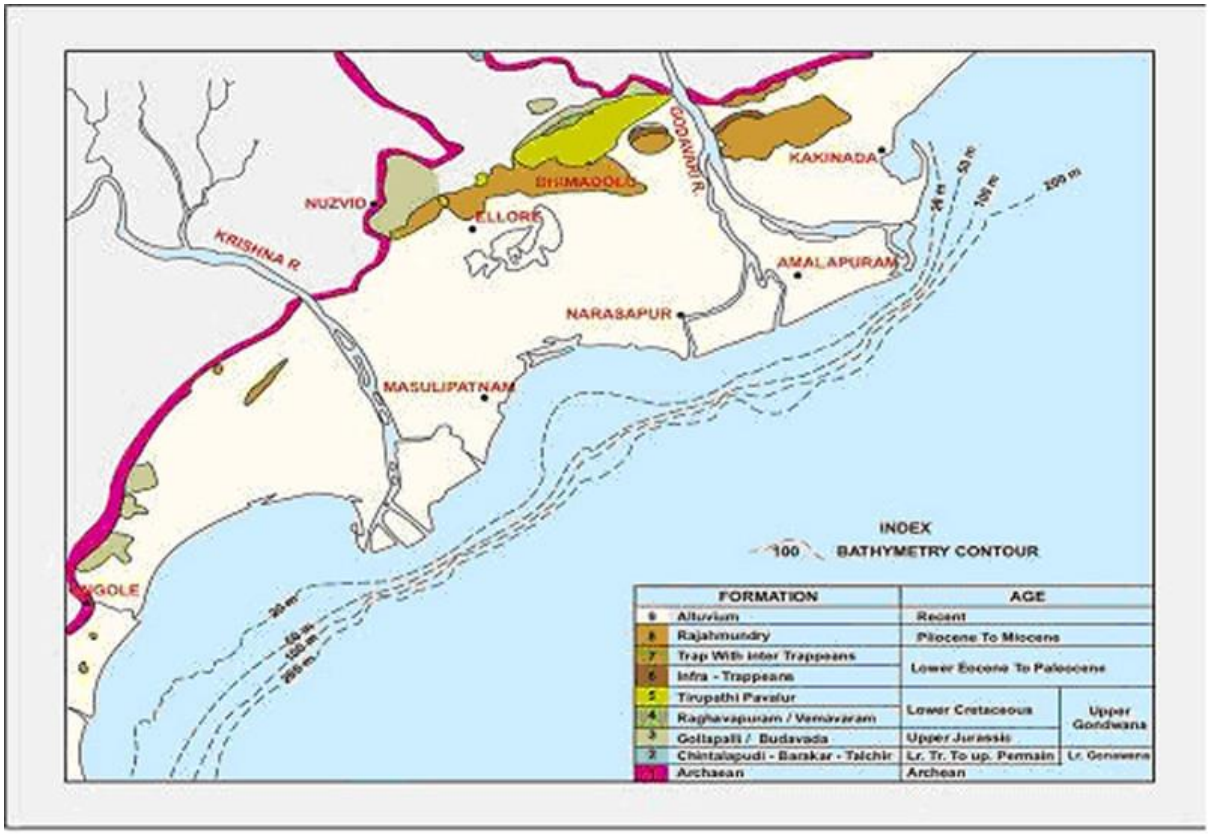


The major geomorphologic units of the Krishna Godavari basin are Upland plains, Coastal plains, Recent Flood and Delta Plains.

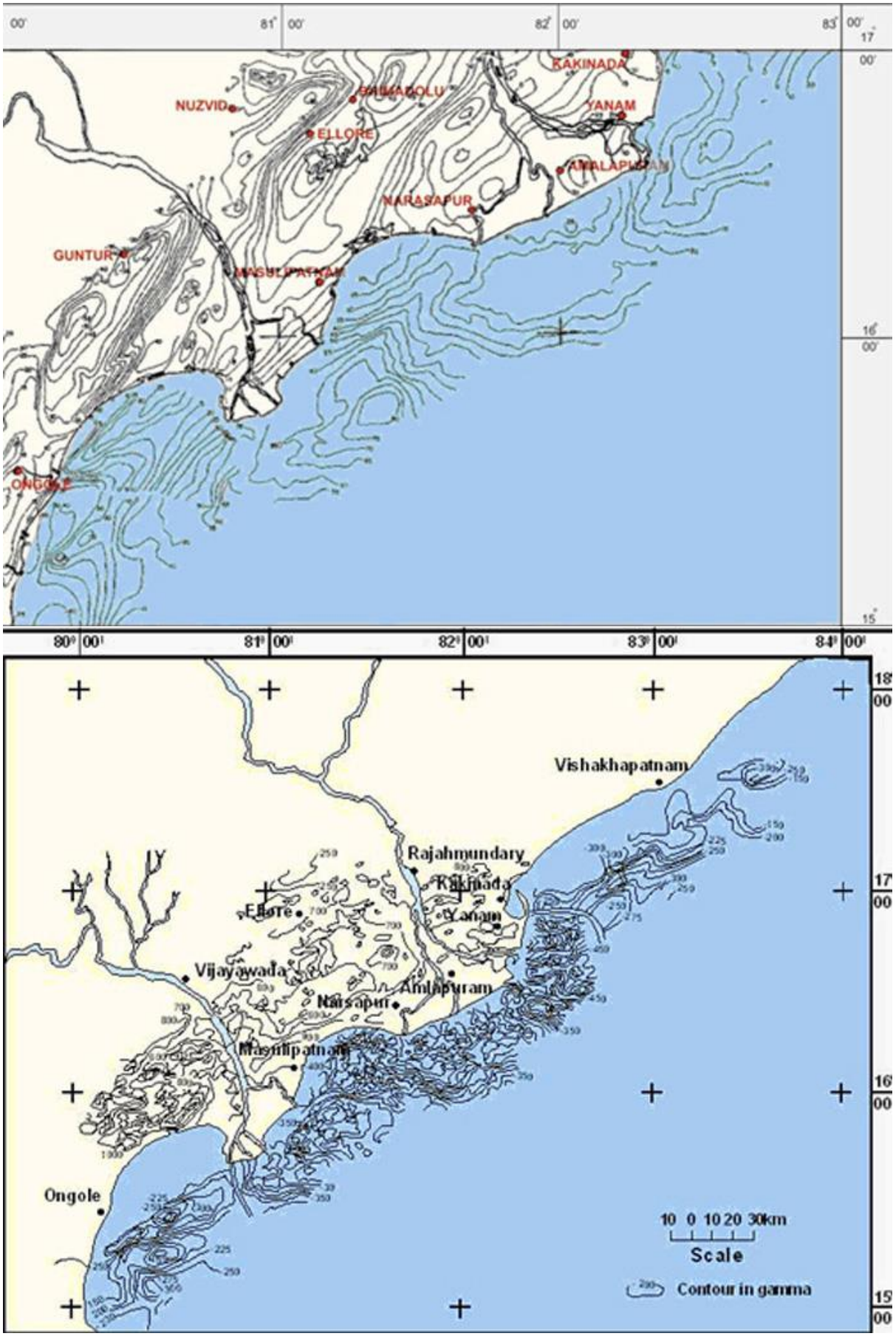
The climate is hot and humid with temperature reaching up to 42 degree C during summer. The mean day temperature varies between 35 C and 40 C during summer and 25 C and 30 C during winter.

Geological/ Geophysical Surveys

ONGC has carried out detailed geological mapping in the area covering 4220 sq. km since 1959. Geological map of Krishna Godavari Basin.



Gravity-Magnetic surveys, in onland part have been carried out by ONGC over an area of 19,200 sq. km. In offshore area, M/s. Prakla Seismos and GSI acquired the gravity-magnetic data for ONGC. Composite Bouguer gravity and composite magnetic anomaly map


KAKINADA
NUZVID
YANAM
ELLORE
NARASAPUR
GUNTUR
ONGOLE
Vishakhapatnam
Rajahmundary
Kakinada
Eluru
Yanam
Vijayawada
Amlapuram
Narsapur
Masulipatnam
Ongole
10 0 10 20 30km
Scale
Contour in gamma

Seismic Coverage
Conventional single fold surveys were initiated in 1965 and upto 1973 about 2,690 line km of data was acquired. CDP surveys commenced in 1973 and so far about 34,642 Line Km. data with foldage varying from 6 to 48 have been acquired. ONGC has also carried out 2,325 Sq. Km. 3D seismic in onland area.

In offshore area, the first surveys of regional nature were carried out during 1964-65. These surveys were followed by multifold 2D / 3D seismic surveys, in shallow to deep waters and transition zone. As on 1st April 2005,(Figures of year 07-08 are to be taken instead of 2005) more than 74,753 Line Km. 2D and 26,508 Sq. Km. 3D seismic surveys have been carried out.

Additionally, during 1972-74, 2,028 km. Refraction data was acquired to study the basement configuration and also shallow reflectors.

More than 225 prospects have been probed by drilling of more than 557 exploratory wells. Hydrocarbon accumulations have been proven in 75 of these prospects (22 oil & 53 gas). Notable oil discoveries are Kaikalur, Vadali, Mori, Bantumilli, Lingala, Suryaraopeta, Gopavaram, Kesanapalli, and Kesanapalli West. The gas discoveries are Adavipalem, Elamanchili, Enugupalli, Narsapur, Razole, Tatipaka-Kadali, Pasarlapudi, Mandapeta, Chintalapalli. Nandigama, Endamuru, Penumadam, Ponnamanda, Achanta, Mullikipalle, Magatapalli, Gokarnapuram, Kesavadasapalem, Lakshamaneshwaram, Rangapuram and Sirikattapalli.

In onshore, so far 141 prospects have been probed by 375 exploratory wells by ONGC, out of which 11 oil & gas pools and 31 gas pools have been discovered and most of them are on production. In offshore ,Sso far more than 84 prospects have been probed by 182 exploratory wells . Hydrocarbon accumulations have been proved in 33 of these prospects (11 oil & gas and 22 gas prospects). About nineteen discoveries have been made by Pvt./JV companies so far in NELP blocks (Fifteen Dhirubhai discoveries by RIL in blocks KG-DWN-98/3 and KG-OSN-2001/2, three discoveries by Cairn Energy Pty. Ltd. (CEIL) in block KG-DWN-98/2 within Mio-Pliocene, 3 discovery by ONGC in the block KG-DWN-98/2 within Plio-Pleistocene sandstone of Godavari formation and one discovery by GSPC in block KG-OSN-2001/3 within Lower Cretaceous). To check the above the shallow and a deepwater discoveries.

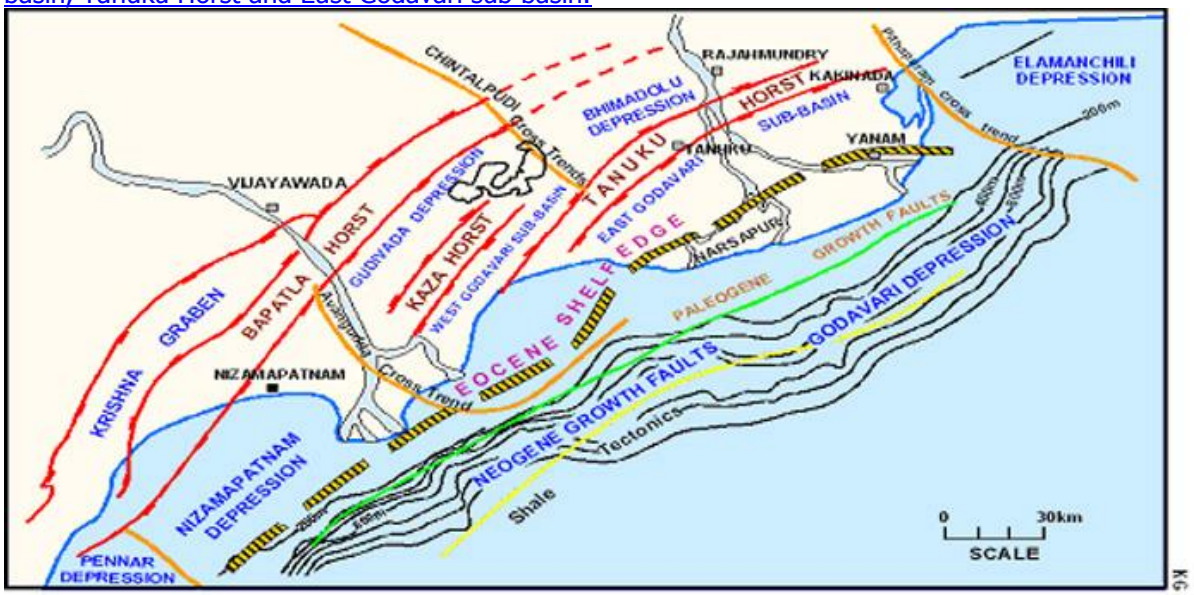
Tectonic History :.
Krishna Godavari Basin is a Continental passive margin pericratonic basin. The basin came into existence following rifting along eastern continental margin of Indian Craton in early Mesozoic. The down to the basement faults which define the series of horst and grabens cascading down towards the ocean are aligned NE-SW along Precambrian Eastern Ghat trend.

The geological history comprises of following stages:

- **Rift Stage:**The basin got initiated through rift / syn-rift tectonics between Permo-Triassic to Early Cretaceous and is essentially characterized by lagoonal to fluvial to occasionally brackish water sediments. The northeastern part of the present onland 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:** The early stage synrift sediments were deposited during early subsidence by tectonic fault systems. Basin subsidence continued along basement bound fault system accommodating synrift 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 Maastrichtian-Danian, the basin experienced major volcanic activity (Razole Volcanism) covering 1600 sq. km. area and having span of 5.5 million years.

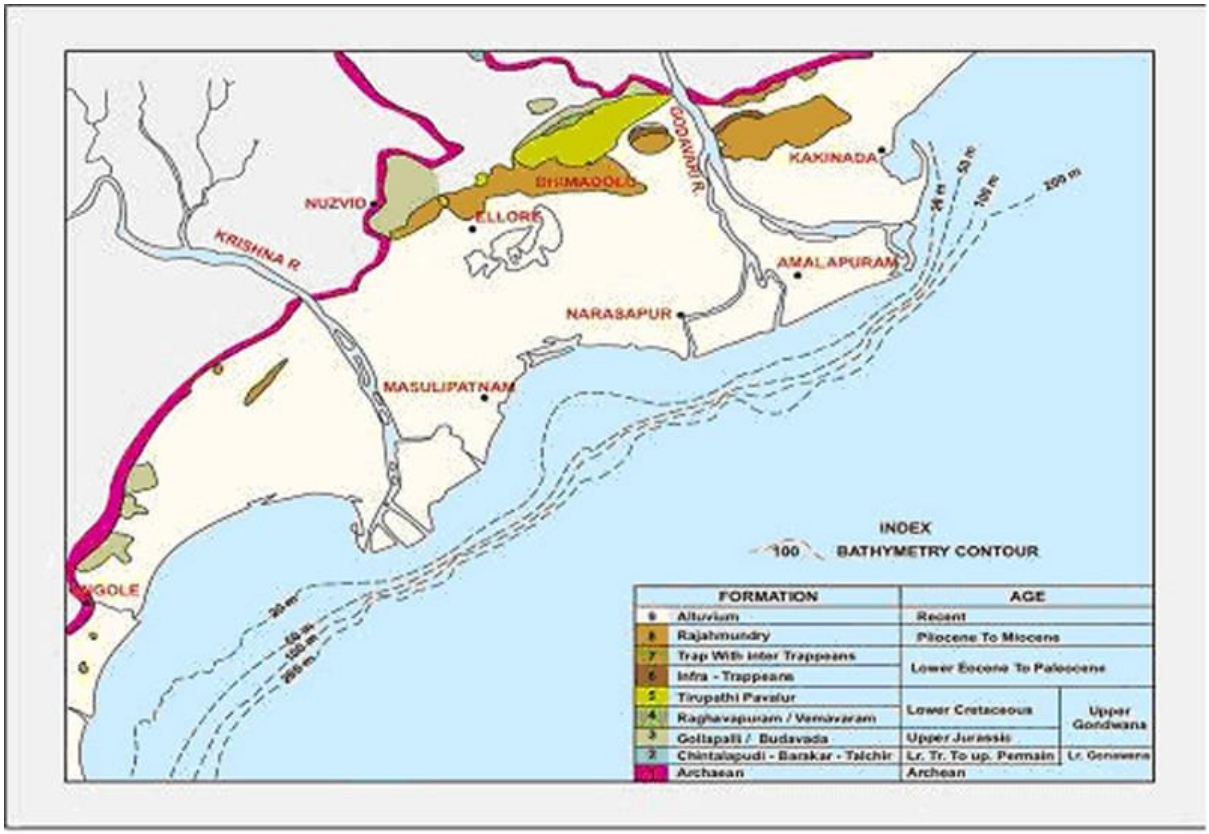
- **Late Drift Stage:**Initial soft collision between the Indian and Eurasian Plates and initiation of Matsyapuri-Palakollu fault appears to have greatly influenced the Paleogene and younger tectonic regiment and the consequent sedimentation pattern.
- Sediment induced Neogene tectonics: Increased gradients for the river systems and increased sediment load coupled with significant sea level falls during Neogene had triggered sediment induced tectonics in the shelf and slope parts of the basin creating highly prospective exploration locales. Some of the recent very significant discoveries in these settings had opened new hydrocarbon opportunities in the Krishna-Godavari basin and necessitated re-estimation of its hydrocarbon resource potential.

The five major tectonic elements of the basin are- Krishna Graben, Bapatla Horst, West Godavari Sub basin, Tanuku Horst and East Godavari sub basin.



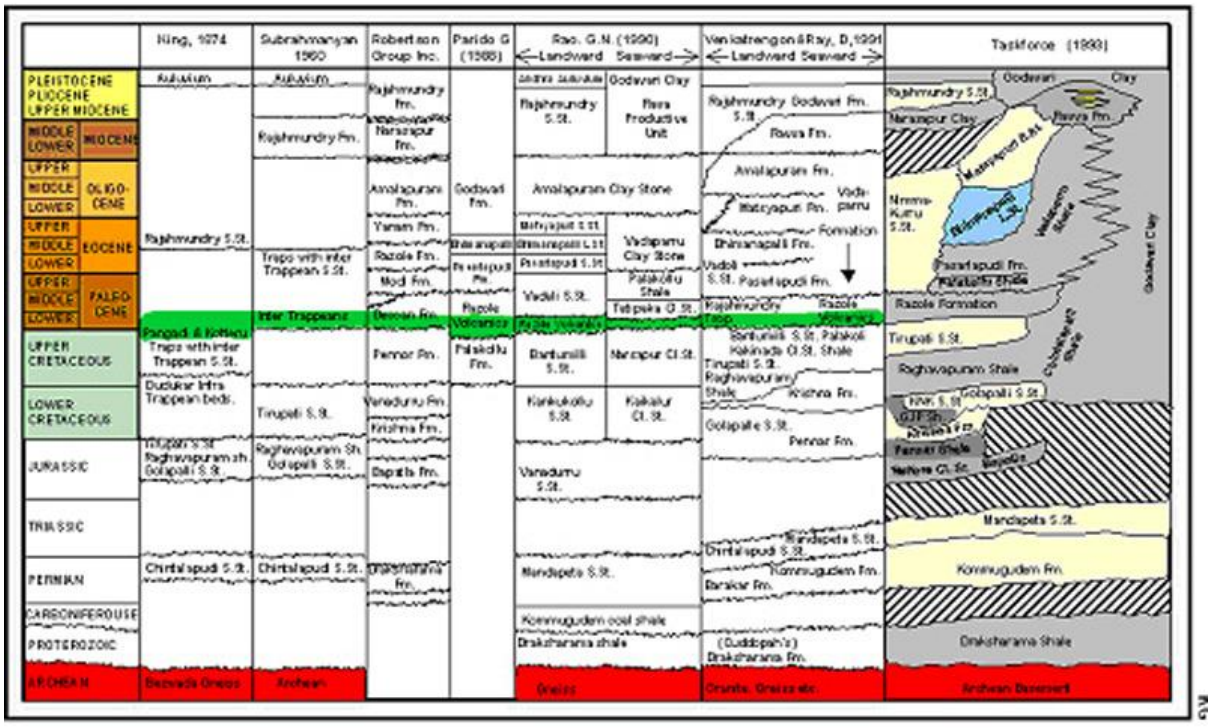
Generalized Statrigraphy :.

In the northwestern and western margins of the basin, out crops of Achaean crystallines and sediments ranging in age from Late Permian to Pliocene are present. However, major part of the basin is covered by alluvium/sea. The geological map of the basin shows the details of outcrop belt .

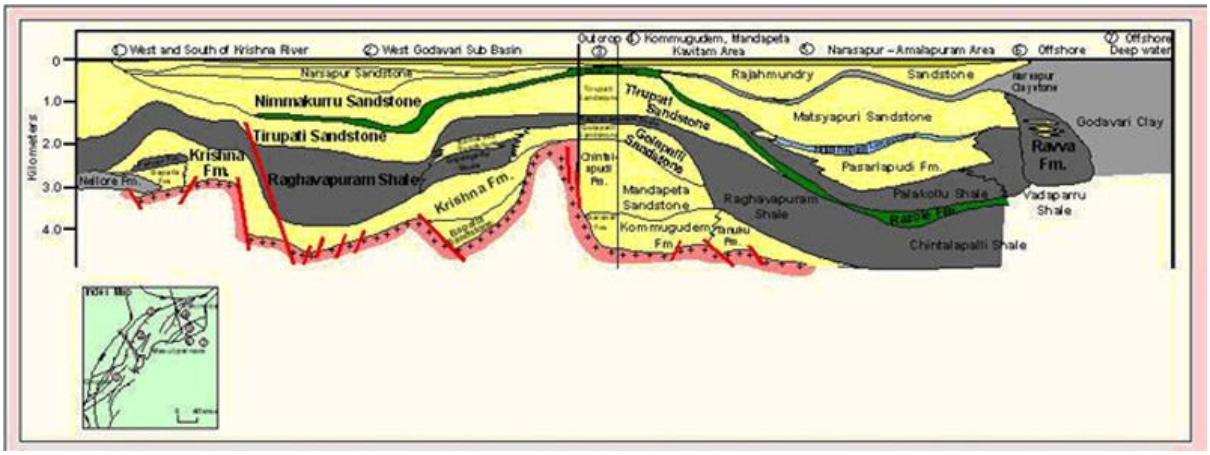


The outcrop and sub-crop lithologic information has been gathered from a large numbers of wells drilled in the shelfal area and onland.

- [The stratigraphy has been worked out.]



- Litho - Stratigraphy Nomenclature.

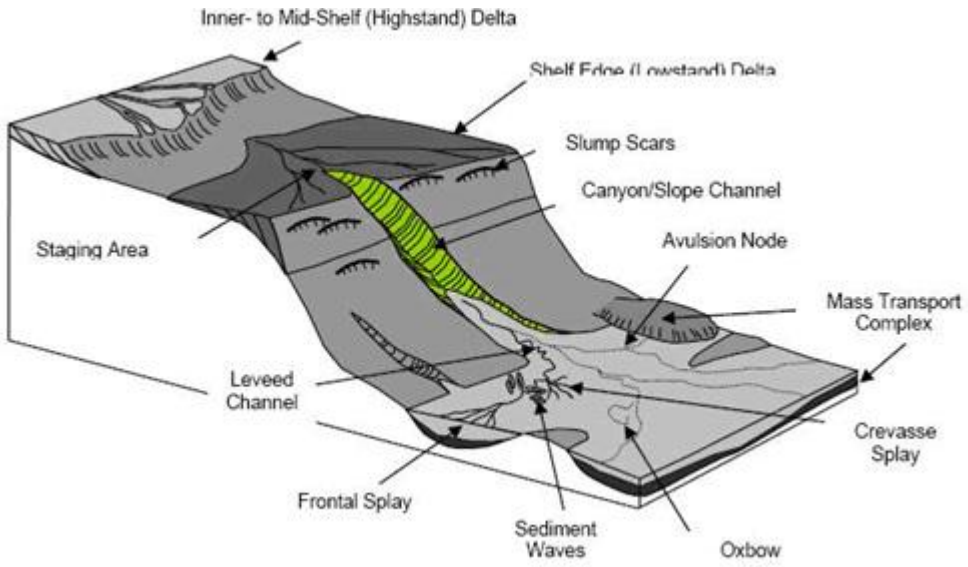


Depositional Environment

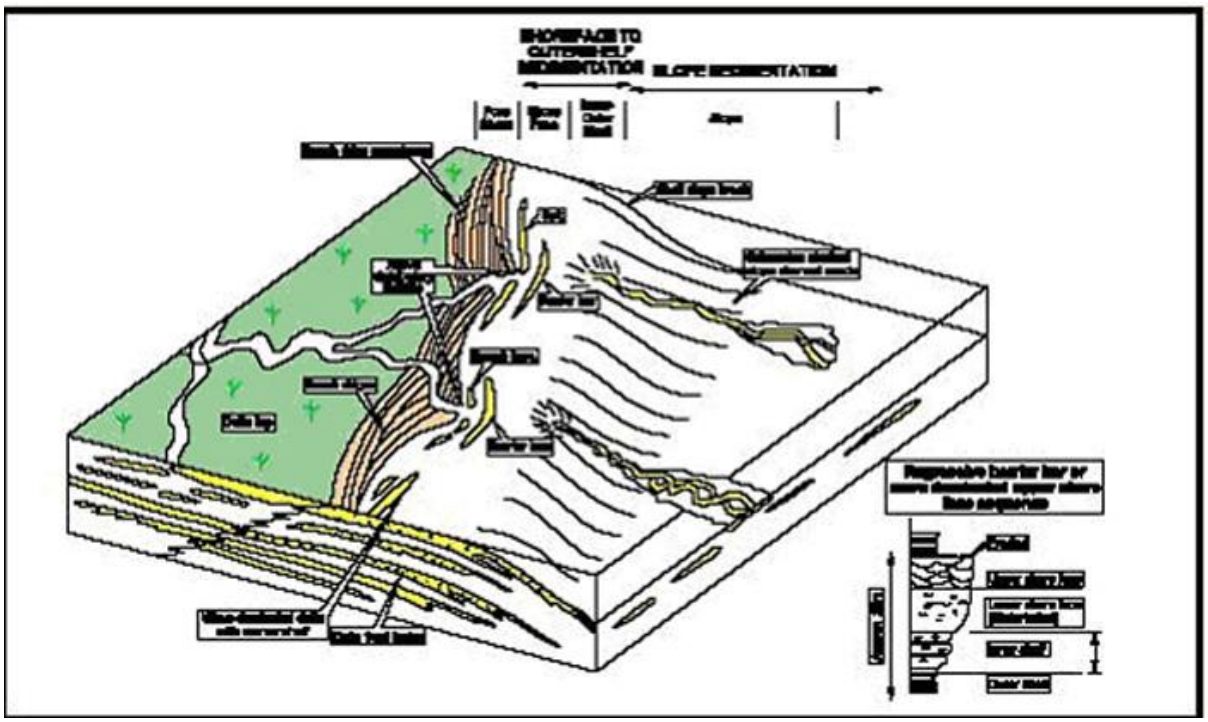
Four distinct depositional systems have been recognized in Krishna Godavari basin. These are - Godavari delta system, Masulipatnam shelf slope system and Nizampatinam shelf –slope system and Krishna delta system.

The maximum thickness of the sediments in Krishna Godavari basin is around 5000 m. Controlling factor of the thick pile of sediments is presence of long linear Gondwana rift valley. Palaeontological evidences suggest a period of slow sedimentation and subsidence but changes in water depth during deposition.

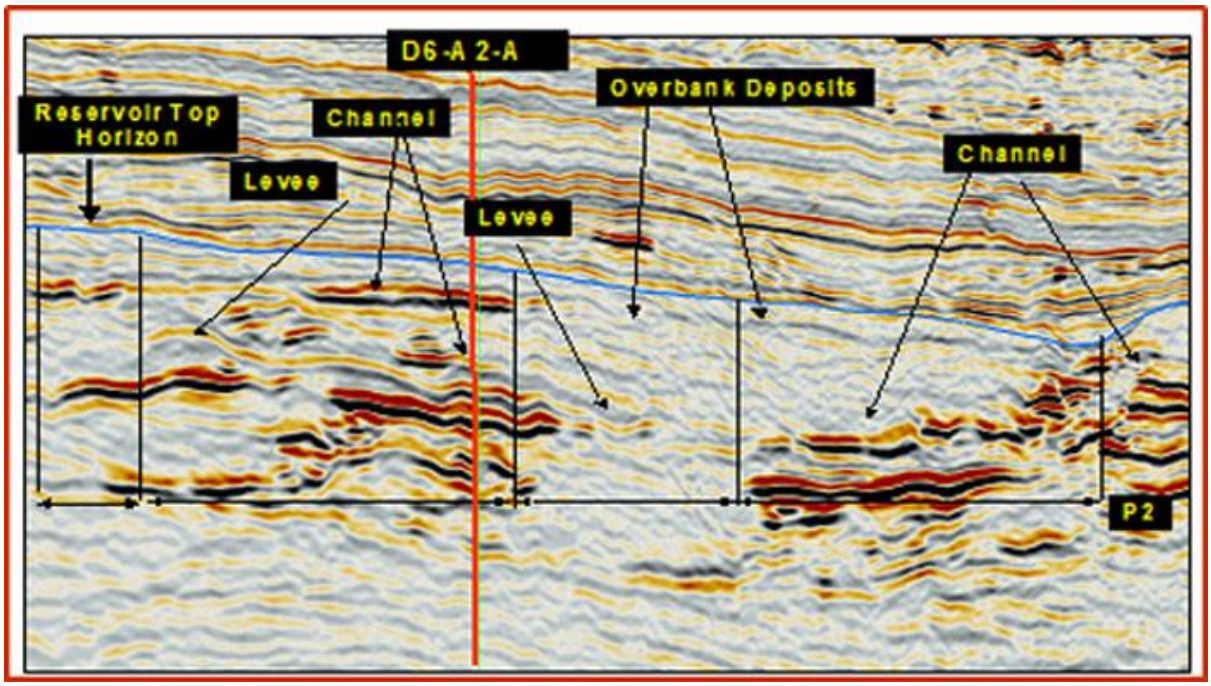
- Tertiary Play : Principal Depositional Elements from Shelfal Staging Area to Basin-Plain



- Krishna Godavari Basin - Depositional Model of the Shallow Offshore



- Seismic section showing spread of Pliocene Channel- Levee complexes and Overbank deposits

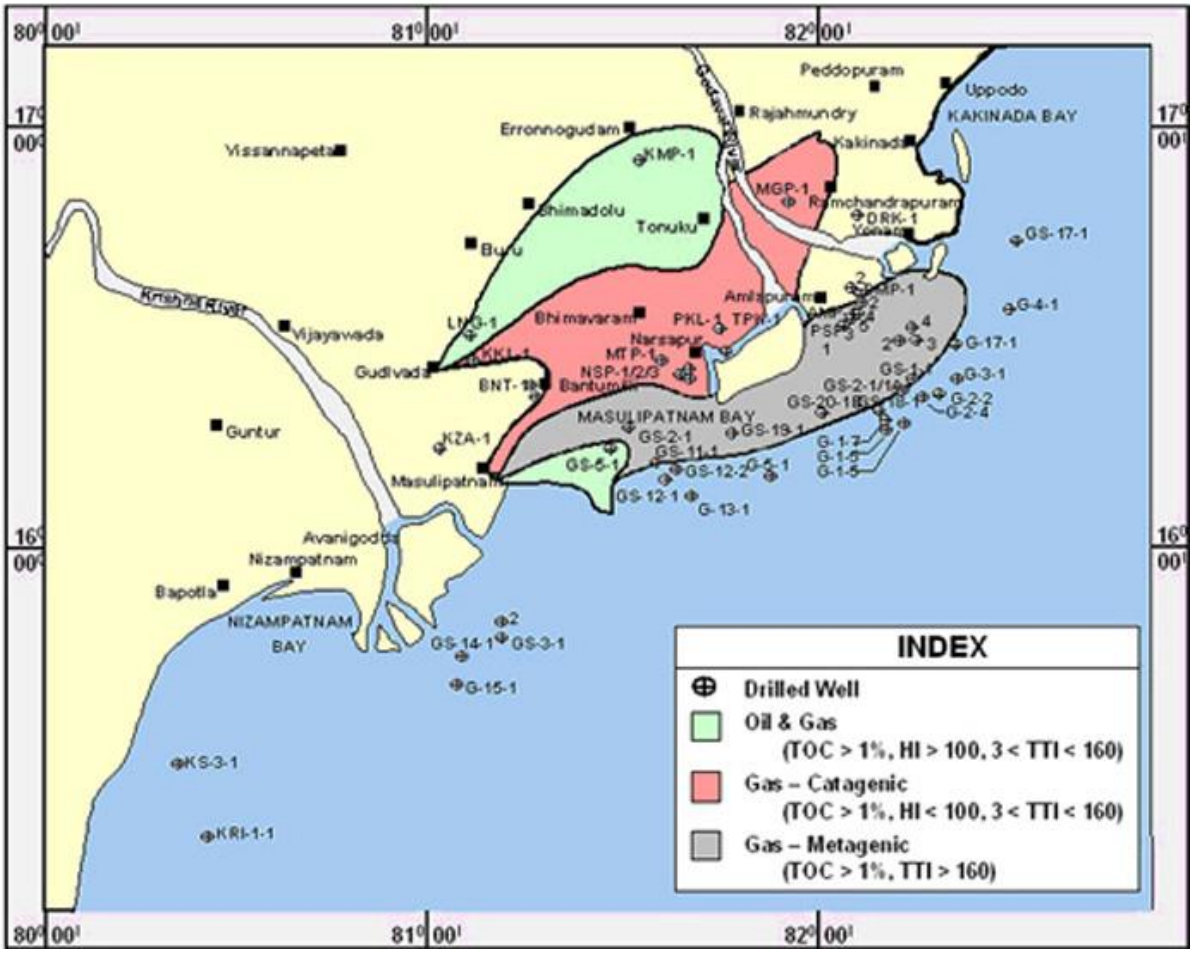


Petroleum System :.

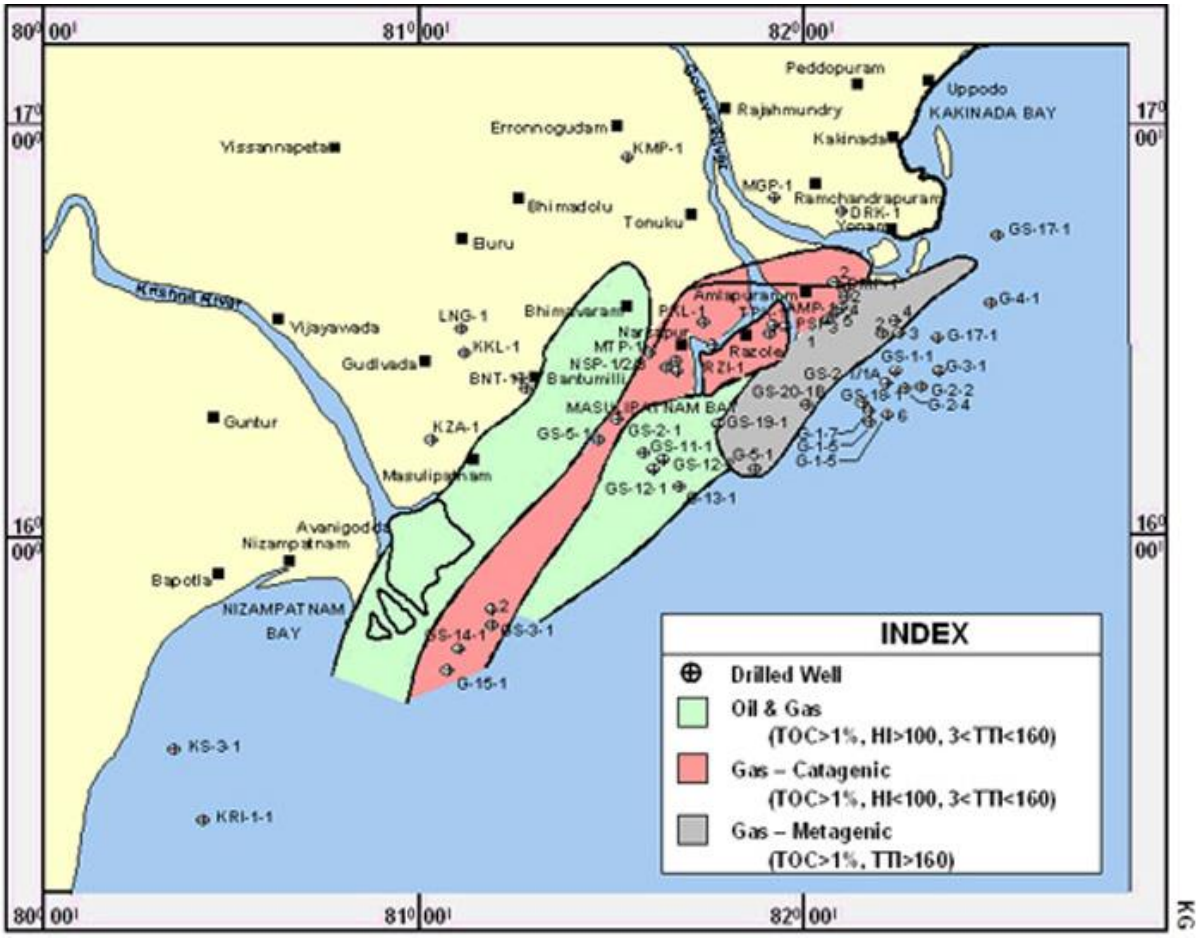
Krishna-Godavari basin is a proven petroliferous basin with commercial hydrocarbon accumulations in the oldest Permo-Triassic Mandapeta Sandstone onland to the youngest Pleistocene channel levee complexes in deep water offshore. The basin has been endowed with four petroleum systems, which can be classified broadly into two categories viz. Pre-Trappean and Post-Trappean in view of their distinct tectonic and sedimentary characteristics. Seismic imaging of Pre-Trappean section poses problems in terms of data quality.

Source rich areas at different stratigraphic levels

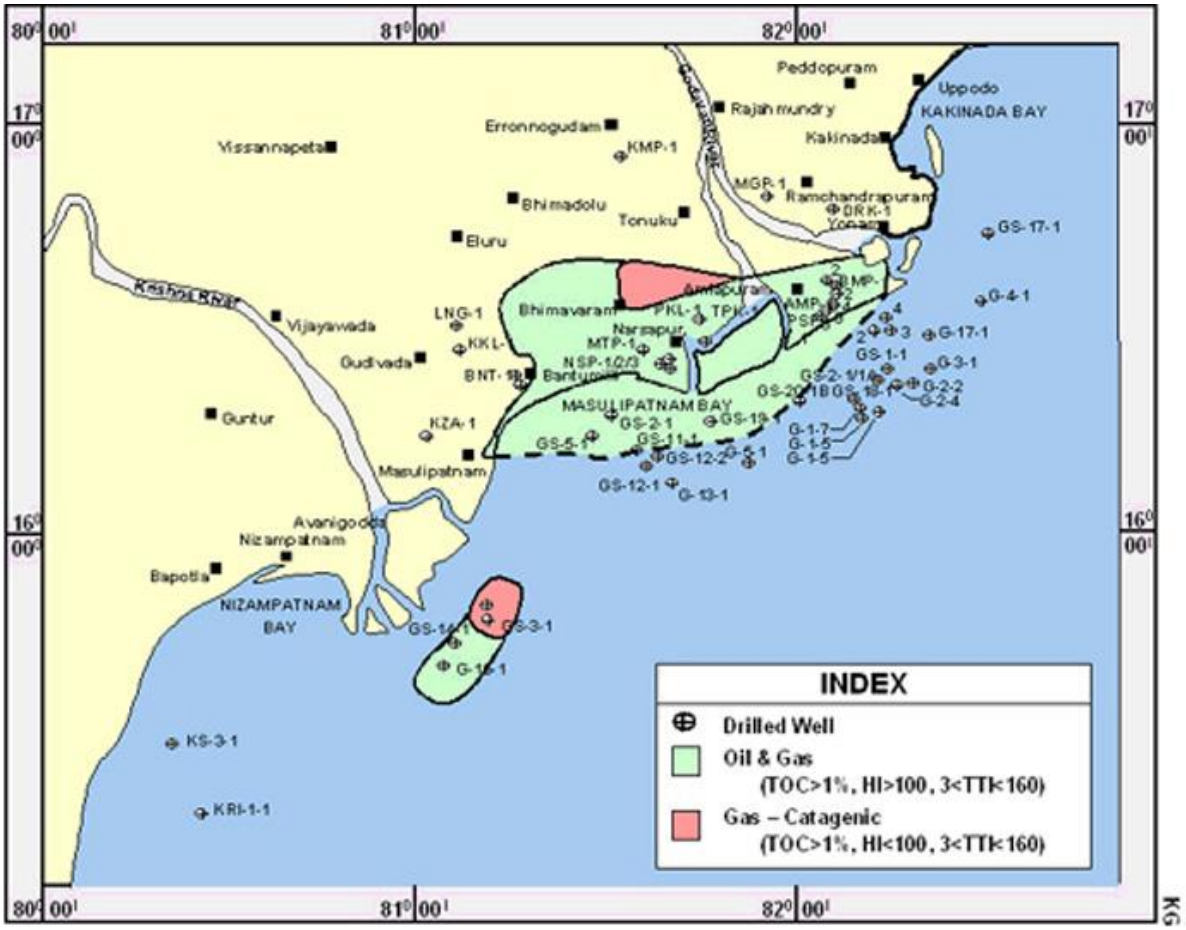
- Hydrocarbon Generation Centres in Cretaceous.



- Hydrocarbon Generation Centres in Paleocene.



- Hydrocarbon Generation Centres in Eocene.



Pre -Trappean Petroleum System

Permo-Triassic Kommugudem-Mandapeta-Red Bed Petroleum System
This is the oldest known petroleum system in the basin.

Source Rock	Kommugudem Formation is the main source rock for this system. It belongs to Artinskian (Upper Early Permian) age. This coal-shale unit is more than 900 m thick in the type well Kommugudem-1.It has a good source rock potential with rich organic matter with TOC ranging between 0.5 to 3% and vitrinite reflectance in the deeper part of the basin is in the range of1.0 to 1.3. Generation threshold occurred during Cretaceous.
Reservoir Rock	Mandapeta Sandstone of Permo-Triassic age is the principal reservoir rock for this system. It may be noted that these sandstones are in general tight and need frac jobs for exploitation. However, porous and permeable patches are also present and chasing them seismically is a major exploration challenge.
Cap Rock	Tight layers within Mandapeta Sandstone and the overlying argillaceous Red Bed act as effective seals.
Entrapment	Entrapment is essentially structural in nature. As mentioned earlier, seismic mapping of pre-trappean section has serious problems due to the presence of a good seismic energy reflector in the form of Basalt above this system affecting the seismic data quality.

Late Jurassic-Cretaceous Raghavapuram-Gollapalli-Tirupati-Razole Petroleum System

Source Rock	Raghavapuram Shale of Lower Cretaceous age is considered as the principal source rock not only for this system but also for the onland part of the basin. Maximum thickness up to 1100 m is recorded in the subsurface. The sequence comprises essentially carbonaceous shale with intervening sands possibly representing brief regressive phases in an otherwise major transgressive phase. The organic matter is dominantly of Type III and III B. The maturity level varies between catagenetic to inadequately matured in different parts of the basin. TOC is recorded up to 2.4%. It has the proclivity for generation of both oil and gas.
Reservoir Rock	Lenticular sands within Raghavapuram Shale possibly representing intervening regressive phases are one of the potential exploration targets; though mapping them seismically poses some challenges as mentioned above. A recent major find in its time equivalent (?) in shallow offshore part of the basin opened up some very exciting exploration opportunities in this sequence. Recent exploratory efforts in deep offshore also indicated prospectivity in Cretaceous sequence Sands within Gollapalli Formation of Late Jurassic-Early Cretaceous in Mandapeta-Endamuru area and its time equivalent Kanukollu Formation in Lingala-Kaikalur area are another potential target in this petroleum system. A northeast southwest trending corridor of Upper Cretaceous Tirupati Sandstone, product of a regressive phase, between southeastern side of Tanuku Horst and MTP fault is emerging as another important target.
Cap Rock	Raghavapuram Shale acts as effective seal for both Gollapalli reservoirs and the sands within Raghavapuram Shale. Shale intercalations within Tirupati Formation appear to act as seal for the accumulations within the Formation. Razole Formation (Deccan Basalt) acts as a regional cap for the pre-trappean hydrocarbon accumulations. It is of interest to note that occasional occurrence of hydrocarbons is noticed within Razole Formation itself, indicating its reservoir potential also.
Entrapment	While the entrapment style is essentially structural, accumulations in Raghavapuram Shale have strati-structural element in their entrapment.

Post-Trappean Petroleum System:

Palakollu-Pasarlapudi Petroleum System

It is the most prolific system in the onland part of the basin contributing major part of the onland hydrocarbon production. It has an abnormally pressured source sequence and a reservoir sequence with more than normal pressures.

Source Rock	The Paleocene Palakollu Shale is the source sequence. It is deposited in considerable thickness in the area to the south of MTP fault with a ENE-WSW alignment paralleling the fault. It shows fair to god source rock potential with proclivity to generate mainly gaseous hydrocarbons. TOC ranges between 0.6 to >5% and is dominantly humic type, rich in inertinite and about 10-20% contribution is from Type II organic matter. Subsidence history of Palakollu Shale suggests generation threshold to be around Middle Eocene.
Reservoir Rock	Sand layers within source rich Palakollu Shale are found to be potential reservoir rocks, though most often with very limited accumulations. Associated high pressures also do not make them attractive targets. Pasarlapudi Formation of Lower to Middle Eocene is the principal producing sequence onland with many potential reservoir levels.

Cap Rock	Laterally persistent shales within Pasarlapudi Formation have been found to act as effective seals for the accumulations within Pasarlapudi Formation. Palakollu Shale encompassing the occasional sands within the Formation also acts as seal for them.
Entrapment	Though structural entrapment is the dominant element for Pasarlapudi Formation, strati-structural element also appears to be occasionally present.

Vadaparru Shale –Matsyapuri / Ravva Formation-Godavari Clay Petroleum System
Discovery of medium sized fields with liquid hydrocarbon in the Coastal Tract, significant discovery of Ravva Field in the shallow offshore and some very exciting mega discoveries in deep offshore parts of the basin have made this youngest petroleum system, a very important one.

Source Rock	: Vadaparru Shale is the principal source sequence. Average TOC for this sequence is about 4%. Organic matter is in the early phase of maturation in the coastal part and increases basin ward. Organic matter is of Type III and has potential to generate both oil and gas. Generation threshold for this sequence is around Lower Miocene. An interesting recent observation regarding the source sequence is that some major gas accumulations in both shallow and deep offshore are found to be of biogenic origin also. This observation throws some interesting challenges in terms of exploration strategies to be adopted especially for the offshore part of the basin.
Reservoir Rock	Sands within Matsyapuri and Ravva Formation and also the sands within Vadaparru Shale are important potential levels and are known to house significant hydrocarbon accumulations in the basin. Recent discoveries in the channel- levee complexes in intra slope terrace/basin setting within Godavari Clay of Pliocene-Pleistocene has opened up hitherto unexplored frontiers of the basin for exploration.
Cap Rock	Shales within Matsyapuri and Ravva Formations, Vadaparru Shale and Godavari Clay act as effective seals.
Entrapment	Though structural element plays dominant role for hydrocarbon accumulations in this system, role of strati-structural element is noticed. Clear understanding of sediment induced tectonics and precise mapping techniques for reservoir facies can yield very rich dividends especially in the younger sequences. Krishna-Godavari Basin endowed with such effective petroleum systems ranging from Permo-Triassic to Pleistocene offer very exciting exploration challenges with matching rewards especially in deep water areas.

Petroleum Plays :.

Syn-rift Mesozoic play
Pennar-Krishna Graben, Nizapattinam depression, both onland and offshore, Synrift grabens in shallow and deep waters (Block KG-OSN-2003/1, KG-DWN-98/1)

Source Rock	Syn-rift Mesozoic sediments
Reservoir	Sandstone
Trap	Structural and strati-structural. Draping over reactivated structural high and wedgeouts.
Depositional Environment	Continental (Fluvial to Laccustrine)

Discovery Wells	KG-15, KG-16, & KG-8, KG-17 (Block KG-OSN-2003/1), KG-D4-MD1 (Block KG-DWN-98/1)
UD-1 (KG-DWN-98/2)	
MA-1(Block KG-DWN-98/3)	KG-D6-MA1 was the 19th exploration well drilled by RIL that was designed to test the hydrocarbons potential of the Cretaceous in the D6 block in offshore Andhra Pradesh, Bay of Bengal. The well is located in water depth of 1189 m in the Krishna Godavari basin. Significant oil discovery was made in this well in the Cretaceous section.

Early Miocene –Mid Miocene Play
Shallow and Deep offshore area, Ravva Field, KG-OSN-2001/1(Dhirubhai-28,36,37), KG-DWN-98/3

Source Rock	Eocene / Cretaceous
Reservoir	Sandstone
Trap	• Structural/Strati-structural growth related /roll over/faulted /unconformity related • Erosional subcrop beyond major sequence boundary (stratigraphic) • Combined fault seal and erosional remnant (strati-structural) • Tilted faults block(structural) • Updip stratigraphic pinch out on sequence boundary.
Depositional Environment	Shore face to deep- water channel and slope fan system
Discovery Wells	Ravva wells R-2 to R-5, 1987-1990.

Hydrocarbon Potential :.
The Krishna Godavari Basin is an established hydrocarbon province with a resource base of 1130 MMT, of which, 555 MMT are assessed for the offshore region (upto 200 m isobath . Several oil and gas fields are located both in onland and offshore parts of the basin. The entrapments are to be expected from Permo-Triassic to Pliocene sediments. The Tertiary hydrocarbon entrapments are so far observed only in offshore part of the basin while Paleogene to Permo-Triassic entrapments are discovered in East Godavari and West Godavari sub-basins in the onland part.

The reservoir facies of Permo-Triassic occur within the well identified source facies at the bottom and overlying Cretaceous argillaceous facies, which act as source as well as cap. In view of the fact that hydrocarbon indications are observed in well KB-4B-1, drilled in the north western part of offshore basin, and also, in well KG-1-B-1, indication of gas with higher hydrocarbon and oil stains in ditch samples collected from Late Paleozoic sediments, imparts the older sequence a fair degree of importance. These older sediments can also be expected to be present upto Krishna island area around the coastal part. The occurrence of gas fields like Mandapeta and Endamuru and indications of hydrocarbons in offshore areas point to the fair potential of this sequence.

The Cretaceous and Early Tertiary accumulations of hydrocarbons are present in several fields e.g., Kaikalur, Bantumilli, Lingala, Narsapur, Razole Chintalapalli etc. both in East as well as West Godavari Sub-Basins. The Cretaceous sequence in offshore wells, like well KB-1B, has also indicated presence of hydrocarbons during drilling. Suitable source and reservoir facies are also reported in this well. The hydrocarbon generation centers in Cretaceous are shown in Figure 10. In view of this, the Cretaceous holds good potential for accumulation of hydrocarbons where some twenty commercial accumulations have been discovered so far.

A number of gas fields are producing from Paleocene reservoirs, particularly in East Godavari Sub-Basin. The Tatipaka, Pasarlapudi, Kadali and Manepalli are the fields located onland, while, GS-8 is occurring in the offshore part of the basin. The hydrocarbon generation centers in Paleocene indicate fair to rich organic content on the basinal side. The indications of gas and its pressure in this sequence justify good potential for Paleocene in the basin. Ten pools of hydrocarbon have already been discovered in this age group.

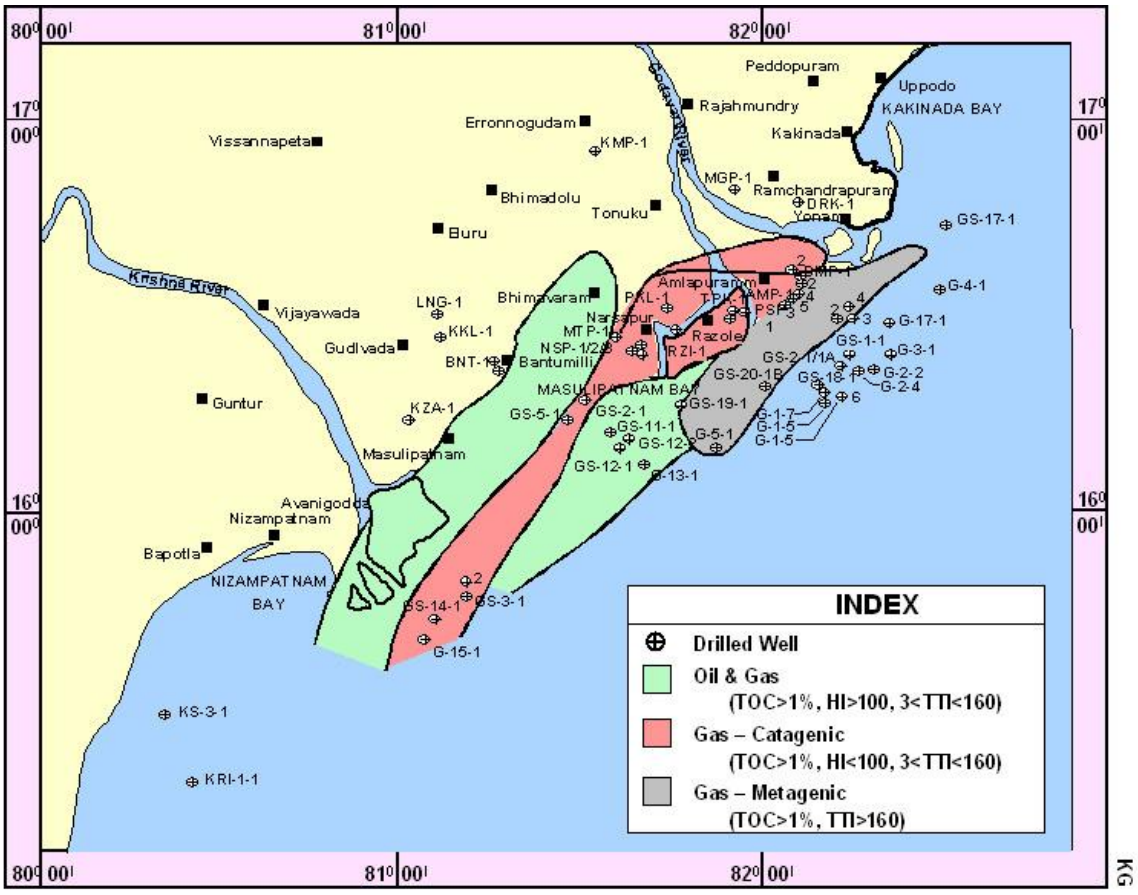


FIG. 55 HYDROCARBON GENERATION CENTERS IN PALEOCENE SEQUENCE – KG BASIN

The Eocene accumulation of gas is observed in Elamanchili, Tatipaka, and Pasarlapudi etc. Mori prospect is oil producer. These oil fields including GS-38 in offshore area indicate good hydrocarbon potential in Eocene sequence. Hydrocarbon generation centers in Eocene . Reefal limestone and associated shelf sediments of Eocene age form another category of hydrocarbon plays, in the lower deltaic areas of Godavari river and shallow waters of Masulipatnam Bay. Drape folds on tilted narrow fault block may have the potential for both oil and gas entrapment. Eight hydrocarbon pools have already been discovered.

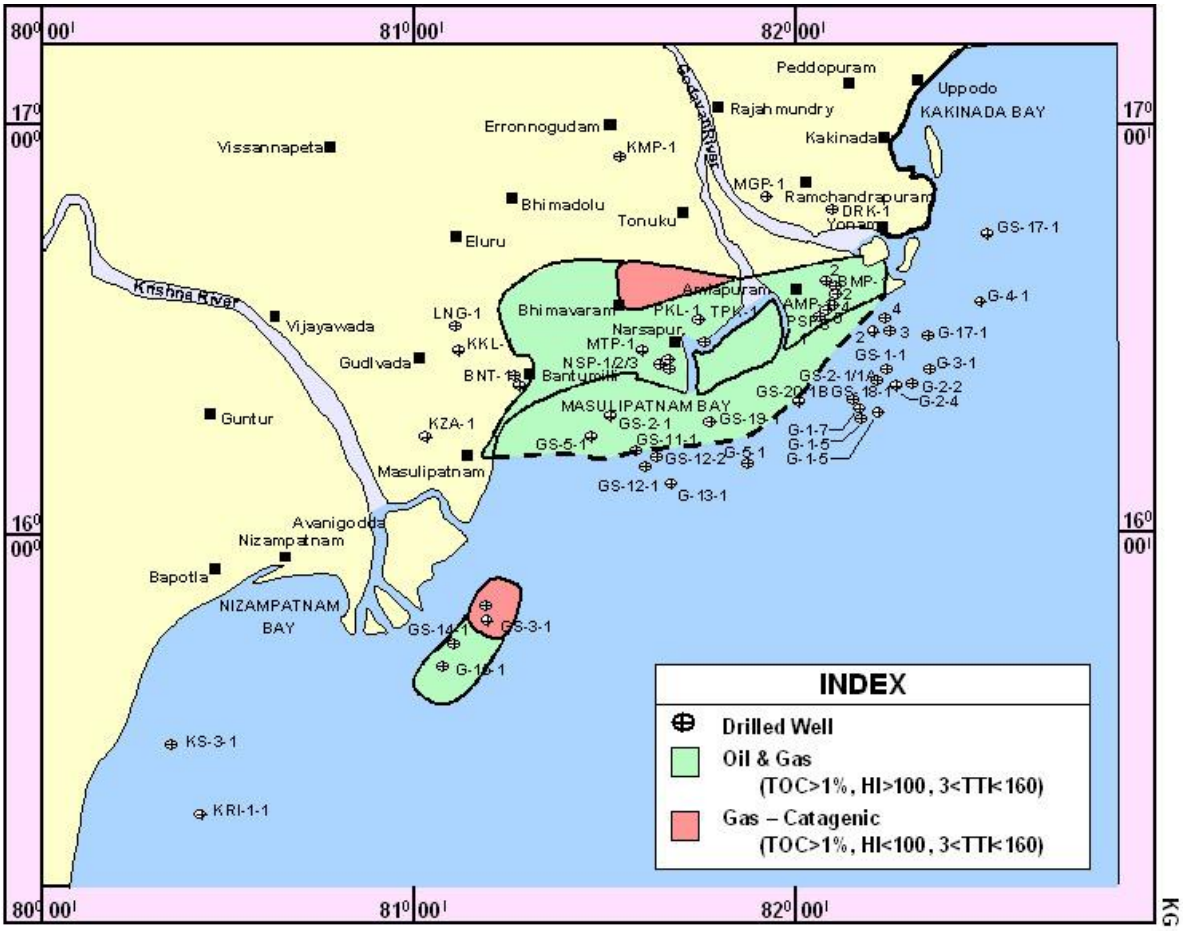


FIG. 56 HYDROCARBON GENERATION CENTERS IN EOCENE SEQUENCE – KG BASIN

The Mio-Pliocene sequence in offshore part is promising. 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. As many as fourteen commercial finds have come from this sequence.