Study of Rift Related Transfer Zones and their Influence on Sedimentation Pattern in North Cambay Basin, India

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This study discusses the interplay of rift architecture and sedimentation at the North Cambay basin in western part of India. Three tectonosedimentary stages have been recognized within Syn rift: Early Rift, Rift Climax and Late Rift. Major transfer fault barriers have been identified, and it is noticed that the Central Horst System (CHS) has undergone major swings and is displaced considerably along these barriers. Till the end of Rift Climax period, basin filling and amalgamation activity of smaller lakes was more in the eastern grabens, while during Late Rift period, the graben filling systems became hyperactive in the western side of the CHS. The main reason of this difference of basin filling is attributed to the variation in tectonic activities of two flanks of CHS. The time structure map prepared at the Trap top indicates remarkable spatial difference between the western and eastern grabens with respect to the CHS. The western grabens are narrower while the eastern grabens are much broader and are flanked by a flexural fault bounded eastern main margin. By the end of rift, eastern grabens remained tectonically active, experiencing continuous subsidence, resulting in a thickened section on the eastern, hanging wall side of CHS. Although tectonics waned significantly on the western side of the CHS, minor fault activations continued till the end of the rift phase, providing subtle control on sedimentary patterns. Four major generation kitchen have been identified during Rift Climax period. The sediments deposited during Late Rift period are identified to be having good reservoir potential. Both reactivated and newly created rift forming faults are believed to have acted as conduits for the hydrocarbons. These faults along with Rift Climax and Laterift source-reservoir couplets form the Synrift GME component.

3D Seismic unravels morphology and architecture of channel complexes and other depositional elements in offshore Bengal basin, India

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Bengal Basin is located along north east coast of India. Its offshore continuation covers an area of 40,000 km2 in the Bay of Bengal. The thick Neogene sedimentary sequence in the study area located in the southern part of offshore Bengal Basin was fed by number of large rivers like Ganga, Brahmaputra, Mahanadi and smaller rivers like Subarnarekha, Baitarani and Brahmani. The sediments in the present day shelf area exhibit a complex depositional history with unique juxtaposition of shallow and deep water sediments in form of deltas, distributary channels, pro-delta sediments and incised canyons, filled up with channel-levee complex deposits.

A study was carried out on the morphology and architecture of different depositional elements and units utilizing different vintages of 2D / 3D seismic and drilled wells data. Geo-Body mapping and attribute studies reveal finer details of the complex system. Special seismic attributes such as spectrally decomposed amplitude, wave-form classifier and 'sweetness' were quiet helpful in understanding the morphological details of the system. The following depositional elements have been brought out. • Delta-Distributary channel complex associated with incised valley and tidal inlets. • Shelfal Canyon cut and fill sequences; • Deep-Water Channel Complex: Fed by large canyon up-dip. These depositional elements do not form part of the canyon fill, but occur down-dip. The sand and silt distribution in the above depositional complexes form the predominant hydrocarbon reservoir units. The numerous reservoir bodies within the above units of varying lateral and vertical extents, are expected to hold the future exploration potential in this frontier basin.

High Impact Palynological Studies in Hydrocarbon Exploration in Indian Petroliferous Basins – A Summary

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The present paper is an updated summary of palynological information which became available in the last few years by Mehrotra and his associates in the effective application of this science in commercially producing basins of India. In Cambay Basin five dinoflagellate biohorizons have been identified within Ypresian with a maximum resolution of 5.8 Ma. In Mumbai Offshore Basin twenty dinoflagellate biohorizons have been distinguished between Ypresian to Miocene with a maximum resolution of 1 Ma. In Cauvery Basin dinoflagellates have been used in dating Cretaceous to Early Eocene sediments. In Krishna-Godavari Basin seventy nine dinoflagellate biohorizons have been identified with a fine time slicing from 0.5 to 1 Ma in Middle Triassic to Holocene sediments. In Assam Arakan seven biohorizons within Thanetian top to Priabanian have been distinguished based on dinocysts; A maximum resolution of 3.3 Ma has been achieved. The data has been presented through 6 palynostratigraphic figures.

Range Tables 1-14 present a summarized account of stratigraphic ranges of stratigraphically most significant angiosperm pollen and dinoflagellate cysts in the above petroliferous basins.

The data presented in this paper is expected to be of use to Indian biostratigraphers particularly those attached with the Industry for generating high impact palynological information in hydrocarbon exploration business.

Evidence for Polyphase Deformation in the Cachar Fold-Thrust Belt of Lower Assam, India: Implications for State of Stress in the Area

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The Cachar fold-thrust belt (FTB), a part of the Assam-Arakan Orogen, is characterized by a series of

approximately symmetric detachment folds, involving a thick, pre-dominantly clastic, Tertiary stratigraphic sequence. North of Cachar Hills and Barak River, the Shillong Plateau, interpreted as a crustal scale pop-up structure bound by two reverse faults, abruptly truncates the structures of the Cachar FTB. The Miocene strike slip Dauki fault is postulated to have nucleated dip slip faulting as the region approached the Himalaya during Pliocene. Seismic and structural data have been integrated to construct balanced cross-sections, which indicate the following stages of structural development: 1: Evolution of approximately symmetric detachment folds due to Late Miocene east-west compression. 2: Continued Late Miocene east-west compression resulting in the formation of out-of-syncline fore-thrusts (e.g. Srikona thrust) and back-thrusts (Badarpur system). 3: An episode of north-south compression (Pliocene), related to reverse fault movement along the Dauki fault, resulting in the development of a series of generally low amplitude east-west trending detachment folds in its footwall. The most significant fold to develop was the Barak River syncline. Haflong thrust, basal detachment for the up-turned North Cachar Hills FTB itself, is folded and consequently exposed south of the Shillong Plateau. Re-folding of the existing structures due to north-south compression has resulted in the development of Type-1 interference structures in the area studied. Evidence for north-south compression also comes from earthquake focal solutions, GPS-geodetic and borehole breakout data. An extremely complicated tectonic stress field exists within the sedimentary prism of the Cachar FTB. A comprehensive study of geologic and neo-tectonic structures, and geophysical data indicate how the stress field in the area evolved through geologic time.

Pore Pressure Modelling in the Cachar Area of Lower Assam, India

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Formation overpressure has been reported in several wells drilled in the Cachar fold-thrust belt, as in many Tertiary sedimentary basins of southeast Asia. No regional model explaining the causal mechanisms for these overpressures exists. A model has been developed using regional data to explain and predict these overpressures. A study of fourteen wells has indicated that a combination of four mechanisms is responsible to variable degrees at different places: 1. High sedimentation and burial rates of Surma sediments during Miocene, leading to disequilibrium compaction. 2. Rapid uplift during detachment folding and later thrust-related folding, under high horizontal shortening rates. 3. Rapid erosion after uplift, also under high horizontal shortening rates. 4. Hydrocarbon buoyancy effect due to possible (substantial) hydrocarbon columns. In the Masimpur area, a pressure transition zone, also a pressure seal has been identified just below the Srikona thrust. It coincides with the brittle deformation zone associated with the Srikona thrust, marked by intense brecciation. Following uplift and erosion, pressure dissipation has been greater in the hangingwall than in the footwall, and overpressures are significantly greater below the Srikona thrust. The pore pressure model has significant implications for the dynamic capacity of the Renji sandstone reservoir. Considering the structural uncertainty regarding the top of reservoir at the crest of Masimpur structure, the Dynamic Capacity Model has been used to predict the possible height of hydrocarbon accumulation. The two extreme scenarios range from an initial water-phase pressure at the fracture gradient (which would prevent any hydrocarbon accumulation) to a substantial gas column. The model developed for the Masimpur structure is applicable elsewhere in the Cachar area too, as validated by existing well data.

Evolution and Hydrocarbon Prospectivity of Gondwanic Satpura Basin, Central India

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Satpura Basin, the westernmost Gondwana basin of Peninsular India, is spread over an area of 12000 sq.kms. A thick sedimentary column, around 6500m in the northern part, in proximity to an established hydrocarbon province promotes Satpura Basin as the most prospective candidate for expanding the horizons of Gondwana hydrocarbons in India beyond the established Krishna-Godavari province.

This communication integrates available geoscientific data to analyze the evolution of Satpura Basin and it's implications in hydrocarbon prospectivity of the basin. Relative dominance of either of the two dominant tectonic influences on the basin, Son-Narmada Lineament and Pranhita-Godavari Fault, and their respective senses of slip appear to control the basin's tectono-sedimintary evolution. Migration of the predominant depocentre is deciphered and concurs very well with regional tectonic observations. A northward sloping basin floor, swinging from a western tilt till Late Permian (Motur) deposition to an eastern tilt since then is interpreted. Strike slip movements along the two dominant tectonic trends resulted in localized transpression, starting during late Motur and terminating with the Late to Latest Permian deposition (Bijori), that gave rise to antiforms. This communication further explores the hydrocarbon potential of the basin as a whole by identifying two possible petroleum systems, Barakar-Barakar(?) and Bijori-Pachmarhi(?), worth pursuing. With an expansive geographical and stratigraphic extent, the former offers a better bet for striking hydrocarbons in the basin compared to the restricted later. All relevant facets suggest the north-western part of the basin to be the most prospective for exploring the Barakar-Barakar(?) Petroleum System.

Extent And Limit Of Gondwana in East Coast Pericratonic Basins Of India And Their Hydrocarbon Potential

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Thick successions of Gondwana sediments occur in the subsurface below the marine Cretaceous successions in the East Coast basins of India. Recent geological studies have added additional biostratigraphic and source-rock data to understand the extent and limits of Gondwana in these basins and their hydrocarbon potentials. In Krishna-Godavari Basin, the Gondwana succession comprises fluviatile Permian and Triassic sediments. They are separated from the overlying marine Lower Cretaceous sequence by a major Jurassic hiatus. In Mandapeta Subbasin (K.G. Basin), gaseous pay-sands, occurring below the "Red-Beds", belong to the Lower Cretaceous Gollapali Formation. However, the older pay-sand zone in the Mandapeta Sandstone belongs to the Triassic Gondwana, and has shown commercial occurrence of hydrocarbon. The shales within Kommugudem and Mandapeta formations, with moderate to rich organic matter are the main source for the Mandapeta and Gollapalli pay-sands, and were within the oil-window since Middle Triassic to Early Neogene. In Cauvery Basin, Gondwana includes only the Lower Permian shale. The overlying Andimadam/Sivaganga Formation, known as Upper Gondwana, belongs to marine Lower Cretaceous sequence. The pay-sand zone within Andimadam Formation is sourced from the shale within this formation having good TOM. The Mahanadi and Bengal basins are with well-developed Lower Gondwana successions. The carbonaceous shale within Barakar and Raniganj formations show potential source. However, occurrence of hydrocarbon within Gondwana is yet to be established. Integrated geoscientific studies may augment in discovering commercial hydrocarbons in buried Indian Gondwana basins as Lower Gondwana are well- known for their commercial hydrocarbon accumulations in Oman, Saudi-Arabia and Australia.

Low Permeability Triassic Gondwana Reservoirs of Mandapeta Graben, Krishna-Godavari Basin, India

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The Mandapeta graben of Krishna-Godavari basin is the only proven Gondwana petroleum system in India. Commercial production of hydrocarbons is obtained from the Middle to Late Triassic Mandapeta Sandstone. This paper attempts to analyze the geological characterization of this sandstone and correlate it with its production patterns.

The Mandapeta Sandstone consists of fine to coarse-grained, pebbly, poorly sorted, massive sandstone with occasional clasts of claystone and rock fragments. The sedimentary structures include graded bedding, cross bedding, flasers and syn sedimentary structures. Quartz wacke and quartz arenite are main rock types with quartz, subordinate feldspar, rock fragments and mica as detrital grains with chloritic and micaceous matrix. The cements include authigenic quartz, hematite, calcite, pyrite and clays. Secondary silica and calcite are the major cements. Intergranular porosity is poor to moderate while the permeability is very low. Poor porosity is mainly due to textural immaturity, poor sorting of the detrital grains and dominance of clay matrix. Pores are further reduced due to early and late diagenetic effects. Compactional features like mica deformation, grain rearrangement and clay coating on grains represent early diagenetic stage. Silica, iron oxide, calcite and authigenic kaolinite have precipitated during this stage. Feldspar leaching was active in early stage due to meteoric water flooding. The late diagenetic stage exhibits the transformation of kaolinite and smectite to illite and chlorite in lower Mandapeta Sandstone. The combined effect of higher matrix content, clay coating, authigenic pore filling clay and pressure solution of grains has led to poor permeability and productivity.

Depositional Environments, Diagenesis, and Reservoir Characteristics of Gondwana Sediments in Dhansiri Valley Area, Assam, India

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This study examines the evolution, depositional settings, and reservoir characteristics of Gondwana sediments in the subsurface of Dhansiri Valley of Assam. Key drilled wells were used as examples for presenting types of depositional regimes, diagenetic and reservoir characteristics of both Lower (Permian) and Upper (Cretaceous) Gondwana sediments. Electrolog and seismic data were used to refine the laboratory-based sedimentological observations.

The Upper Gondwana sediments were deposited as alluvial fans with minor marine influence. Lower Gondwana sediments (equivalents of Talchir Formation) were possibly deposited as a part of marine fan delta with debris flows. The depositional environments and the resultant petrofacies are controlling the reservoir properties of the sandstones. Feldspathic arenites are common sandstones with iron oxides, silica, and calcite as cements. The preservation of intergranular porosity has been fair to good. Microporosity is present in altered feldspars and pore filling clays.

The presence of radial monosaccates viz., *Plicatipollenites sp*, *Parasaccites sp*, *Virkkipollenites* along with trilete spores *Microfaveolatispora sp*, *Microbaculispora sp* and *Horriditriletes sp* suggest Early Permian (Asselian-Sakmarian) age. Presence of Leiosphaeridia suggests marine influence during Early Permian times. Presence of characteristic palynofossil viz., *Plicifera delicata*, *Ornmentifera echinate*, *Tricolporites sp*, *Cyclinospora reduncus*, *Staplinisporites sp*, *Cicatricosisporites sp*, *Classopollis sp* and *Callialosporites sp* suggest Early Cretaceous (Aptian-Albian) age.

The geometry of the sandstone reservoirs is being controlled by the direction and extent of grabens/half grabens, which are well delineated by seismic interpretation. Better sorting associated with stream-influenced sediments for the continental deposits and reworked marine sediments will make good reservoirs.

Tectono-Sedimentation Model And Hydrocarbon Potential Of Gondwana Sediments In Pranhita Godavari and Krishna Godavari Basins, India

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Gondwana sediments in the study area are confined within a NW-SE trending linear trough called Pranhita Godavari (PG) graben, also known to extend underneath the later formed Krishna Godavari (KG) basin, India.

Detailed geological and geophysical analysis brought out an episodic tectonic model for these sediments. The first stage of heating and rifting, initiated during Early Permian, resulted in to the formation of Pranhita Godavari graben. Second rifting was associated with the continental break up of Gondwanaland (Early Jurassic) and continued upto Early Cretaceous (Neocomian). As a result the transverse Krishna Godavari basin, one of the several Indian coastal Gondwana basins, formed with northeast-southwesterly oriented depocenters of syn-rift sediments. The impact of block movement and upliftment during Jurassic rifting along the rift shoulder caused inversion within Jurassic (Gollapalli Sandstone) and underlying sediments. During drifting stage (Aptian) thermal cooling and associated isostatic upliftment in the continental part resulted in pronounced southeasterly tilt and reversed the course of fluvial system towards SE, which is followed by widespread marine transgression in KG basin.

The sedimentary fill of Permo-Carboniferous to Late Triassic period is mainly of fluvial origin. Whereas, Gollapalli Sandstone was deposited at a close proximity of the provenance under fluvial to shallow marine environment.

Barakar Coal-Shale facies of Lower Gondwana sequence is the only matured source rock in the area. As a result of superposed basin tectonics it has been proved to source both Triassic and Late Jurassic reservoirs in PG and KG basins. Hydrocarbon entrapment is controlled by the superimposed fault pattern (older, NW-SE and younger, NE-SW) resulted by episodic rifting.

Tectono-Sedimentation Analysis of rift sediments of West Godavari Sub-Basin and Its Implications for Hydrocarbon Prospectivity of Krishna Godavari Basin

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Pranhita-Godavari, Krishna- Godavari (PG-KG) basin is situated on east coast of India. Exposure of Eastern Ghat orogenic belt remnants, limit coastal KG basin in N and NW. Towards SE, this basin extends into Bay of Bengal.

Krishna- Godavari is a poly-historic basin with three superposed fossil rift stages to pericratonic stages of development. Basin is divided into several sub-basins by a series of horsts formed during Mesozoic rift phase, which is superposed over Permo-Triassic (NW-SE trending) Gondwana fossil rift superposed over PreCambrian Eastern Ghats. Number of orthogonal cross trends are observed over KG rift, akin to PG orthogonal trend. All observed transverse cross-trends are responsible for shifting general trend of structures and their interactions have played a vital role in basin modifying tectonics and in generating suitable anticipated prospective hydrocarbon corridors.

A regional study was undertaken to asses hydrocarbon prospectivity of Gondwana and Cretaceous sediments in Gudivada and Bhimadolu Grabens of West Godavari sub basin.

Study brought out integrated picture of both Gudivada and Bhimadolu grabens with their tectono-sedimentation pattern, stratgraphic units ranging from Permian to Cretaceous age and their lateral and vertical geometrical extent was done.

Jurassic Gajulapdu Shale-Kanukollu Sandstone Petroleum System and the Cretaceous Raghavapuram Petroleum System are active in Gudivada Graben where as Permo-Triassic Gondwanic Kommugudem-Mandapeta Petroleum System along with Cretaceous Raghavapuram Petroleum System are operative within Bhimadolu Graben.

Analysis incorporated 2D seismic data of about 2,200 LKM and point data from 58 drilled wells. Integration of litho-facies, structural frame-work, sedimentological and source rock studies enabled to identify three distinct petroleum systems as well as prospective areas. Tectonic evolution and associated sedimentation pattern are inferred to be key factors for hydrocarbon entrapment in these identified corridors.

Evolution of Riftogenic Stratigraphic Sequences in Multi Segmented Rift Basin: It's Role in Evolution of Petroleum Systems of Krishna-Godavari Basin, India

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Krishna- Godavari basin is conspicuous by its outline on East coast of India. It presents a fully developed passive margin sequence in Northern part of basin while in Southern part it is characterized by en-echelon interior fracture and sags. Rift architecture controlled by fault geometry is itself modified by pre existing fabric of the Eastern ghat mobile belt and Pranhita –Godavari trend. Sixteen juxtaposed tectonic blocks showing horst & graben morphology provides a challenge to make spatio-temporal correlation across the sub basin. Authors, by comprehensive studies of seismic, well data and assimilation of biostrat. and sedimentological data brought out a workable model for exploration in this basin. This tectono-sedimentation model suggests the deposition of sediments under pre, syn and post rift phases during rifting and drifting of Indian plate from Gondwana assemblage, where time to time activation of various ridges separating the sub basin played a major role in providing seclusion and acting as provenance occasionally. The Early riftogenic sedimentation during Permo Triassic times forms the floor for the divergent margin sequence, while Synrift sequence is present throughout the basin. Early drift phase is represented by deltaic facies of Krishna Godavari river system. Seven petroleum systems have been identified, and through these studies the elements of these petroleum systems are being attributed to different phases of basin development. The regional correlation and tying up of reflectors in seismic and wire line logs brought out the depositional model for various litho units and provides a lead for exploration in contiguous sub basins which were unexplored and thought to be of less priority, thus adding prognosticated reserves in this hitherto less explored basin.