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AN OVERVIEW OF PRANHITA-GODAVARI SEDIMENTARY BASIN, TELANGANA, INDIA

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ABSTRACT

Pranhita-Godavari (P-G) Basin occurs in two parallel NW-SE trending sub-basins the western and the eastern), situated at the junction of Dharwar and Bastarcratons, anddeveloped after amalgamation of the craton in palaeoproterozoic. Three sub-basins are identified in this P-G basin. They are namely eastern Albaka, central Pakhal, and western Chandarpur. The aggregate thickness of the sediments of the P-G basin is estimated at about 6000mt. The Pakhal belt extends from Khammam in the south to Adilabad in thenorth. The Albaka belt extends from Bhadrachalam in the south to Chandarpur in thenorth. The P-G Basin sediments deposited in a time span of 200.Ma from lateCarboniferous/early Permian to Cretaceous.Generalisedlitho-stratigraphic succession ofthe Gondwana sediments includes Talchir, Barakar, Barren measures, Kampthi (lowerGondwana group) Maleri, Kota, Gangapur and Chikial formations (upper Gondwanagroup). Two Proterozoic succession of the P-G super group are divided into four majorgroups, namely Mallampalli, Mulugu, Penganga and Sullavai separated by three regional unconformities. The sediments of the P-G basin strike NW-SE with moderate dips towards NE. A 3000mt. thick Gondwana lithic fill consisting of multifacies associationsis preserved in this NW-SE oriented intra-cratonic basin set across the EasternGhatComplex (EGC). The depositional environment varied from galcio-lacustrine to highly sinuous fluvial. The P-G basin is among the Indian Sedimentary basins that have been identified as having hydrocarbon potential. Two blocks have been awarded in the basin PG-ONN-2-1/1 and GN-ON-90/3, while work in the block GN-ON-90/3 has been heldup due to the Naxalite problem for the past 13 years. The block, PG-ONN-2001/1 was awarded to ONGC under the NELP-III in 2003 and is the only block awarded in the P-Gbasin in the NELP era. The other block, GN-ON-90/3, was awarded in the *fourth roundof the pre NELP era in 1993 to partners HOEC and Mafatlal Industries Limited (MIL).Incidentally, ONGC is also the license for this joint venture block. The delays have set back the investigation for hydrocarbons in the under explored P-G basin by more than 15 years. The basin covers the states of Andhra Pradesh and Maharashtra. The P-G basin is a potential Shale Gas basin. The Shale characteristics of P-G basin especially in the lower Gondwana group with TOC% is 6.4%, VRo% is 0.67 and Kerogen type is III.Shale Gas exploration in India is in nascent stage, ONGC has already initiated theprocess and 1st Shale Gas exploratory well is under drilling in Bengal basin. Initiatives being taken by Government of India through DGH & MOPNG to have internationalmulti task ventures is a welcome step in this direction. We are awaiting for the 1st bidround of Shale Gas blocks proposed to be offered by MOPNG by the end of 2011.*

KeyWords: Pranhita-Godavari basin, Godavari super group, palaeoproterozoic, intra-Crotonic rift, lithostratigraphy, unconformities, Gpndwana group, Shale Gas.

1. INTRODUCTION

The Pranhita-Godavari (PG) Valley is a major repository of Proterozoic sedimentary rocks in the Indian peninsula, and is generally believed to be an intracratonicrift basin. The basin filling sedimentary rocks, defined as the Godavari Supergroup(Chaudhuri and Chanda, 1991), are mildly deformed and weakly metamorphosed. Similar Proterozoic cratonic successions developed in several basins in the Indian peninsula during the Mesoproterozoic and Neoproterozoic, and were designated as 'Puranas' by Holland (1906). The available age data indicate that the Godavari Supergroup of the PG Valley, a major Purana basin, encompasses a vast time span of more than 600 Ma, (1330 ^{A} 53 to 790 ^{A} 30 Ma, Vinogradov et al., 1964; Chaudhuri and Howard, 1985; Chaudhuriet al., 1989). The succession of the Godavari Supergroup is punctuated by several major unconformities, a few of which are traceable throughout the basin. The unconformity-bound sequences exhibit well preserved signatures of deposition in wide ranging depositional environments, under variable tectonic and climatic regimes. The successionis ideally suitable for basin analysis, and provides opportunities to delineate different stages of basin evolution.

The stratigraphic succession of the Godavari Supergroup has been studied by a large number of workers (King, 1881; Heron, 1949; Basumallick, 1967; SrinivasaRao et al., 1979; Chaudhuri, 1985; SreenivasaRao, 1985, 1987). With the exception of the earliest work by King (1881), the majority of these studies are essentially local in nature. Regional aspects of stratigraphic development and depositional trends have not yet been adequately constrained to address the problem of correlation on a basin-wide scale, and allow for basin analysis.

This paper attempts to address the Basin occurs in two parallel NW-SE trending sub-basins (the western and the eastern), situated at the junction of Dharwar and Bastarcratons, and developed after amalgamation of the craton in palaeoproterozoic. Three sub-basins are identified in this P-G basin. They are namely eastern Albaka, central Pakhal, and western Chandarpur. The aggregate thickness of the sediments of the P-G basin is estimated at about 6000mt. The Pakhal belt extends from Khammam in the south to Adilabad in the north. The Albaka belt extends from Bhadrachalam in the south to Chandarpur in the north. The P-G Basin sediments deposited in a time span of 200 Ma from late Carboniferous/early Permian to Cretaceous.Generalisedlitho-stratigraphic succession of the Gondwana sediments includes Talchir, Barakar, Barren measures, Kampthi (lower Gondwana group) Maleri, Kota, Gangapur and Chikial formations (upper Gondwana group). Two Proterozoic succession of the P-G super group are divided into four major groups, namely Mallampalli, Mulugu, Penganga and Sullavaiseparated by three regional unconformities. The sediments of the P-G basin strike NW-SE with moderate dips towards NE. A 3000mt. thick Gondwana lithic fill consisting of multifacies associations is preserved in this NW-SE oriented intra-cratonic basin set across the Eastern Ghat Complex (EGC). The depositional environment varied from galcio-lacustrine to highly sinuous fluvial. The P-G basin is among the Indian Sedimentary basins that have been identified as having hydrocarbon potential. Two blocks have been awarded in the basin PG-ONN-2-1/1 and GN-ON-90/3, while work inthe block GN-ON-90/3 has been held up due to the Naxalite problem for the past 13 years. The block, PG-ONN-2001/1 was awarded to ONGC under the NELP-III in 2003 and is the only block awarded in the P-G basin in the NELP era. The other block, GN-ON-90/3, was awarded in the fourth round of the pre NELP era in 1993 to partners HOEC and Mafatlal Industries Limited (MIL). Incidentally, ONGC is also the license for this joint venture block. The delays have set back the investigation for hydrocarbons in the under explored P-G basin by more than 15 years. The basin covers the states of Andhra Pradesh and Maharashtra. The P-G basin is a potential Shale Gas basin. The Shale characteristics of P-G basin especially in the lower Gondwana group with TOC% is 6.4%, VRo% is 0.67 and Kerogen type is III. Shale Gas exploration in India is in nascent stage, ONGC has already initiated the process and 1st Shale Gas exploratory well is under drilling in Bengal basin. Initiatives' being taken by Government of India through DGH & MOPNG to have international multi task ventures is a welcome step in this direction. We are awaiting for the 1st bid round of Shale Gas blocks proposed to be offered by MOPNG by the end of 2011

.The analysis of the basin is based essentially on the review of published records and maps, supplemented by unpublished data where necessary.

2. PURANA BASINS OF INDIA

The large cratonic landmass of peninsular India witnessed the development of several large cratonic basins at the Palaeoproterozoic-Mesoproterozoic transition, and also during the Mesoproterozoic and Neoproterozoic (Chaudhuri et al., 1999). The basins hosted extensive deposits of terrigenous sediments, derived from the cratonic hinterland, and carbonates. The basin-filling deposits are very weakly metamorphosed, and are, in general, only locally deformed, and preserve the pristine sedimentary characteristics. The sedimentary successions are comparable with extensive cratonic deposits of North America (Sloss, 1963). Australia (Preiss and Forbes, 1981), and analogous Proterozoic-early Palaeozoic successions of other cratonic areas.

The origin of cratonic Proterozoic basins of peninsular India is still not well constrained. Chaudhuri et al. (2002) reviewed several aspects of the stratigraphy, sedimentology and structural geology in three major Purana basins, namely, the PG basin, Chattisgarh basin and Cuddapah basin (Fig. 1), and suggested that these basins developed as cratonic rifts. It is noted that localization as well as orientation of the basins are controlled by pre-existing week zones of Archaean age. The PG basin occurs as a NW-SE trending megalineament along a tectonic line marking the contact between two major Archaen nuclei, the Dharwar and Bastarcratons (Fig. 1). The Cuddapah basin occurs to the southwest of the PG Valley, covering an extensive area of the Dharwarcratonic block, whereas several Proterozoic outcrops of various dimensions occur in the Bastarcratonic block, to the northeast of the PG Valley.

The available radiometric data indicate that the basin-filling successions, occurring in very close geographic proximity, had a temporally overlapping history of evolution. In the absence of detailed analysis of lithofacies, stratigraphy, and palaeogeography, the original extension of the basins cannot be estimated with a high level of confidence. However, lithologic similarities of stratigraphic horizons occurring indifferent basins prompted the early workers (e.g. King, 1881) to propose a correlation between them. This implies that the evolution of the PG basin, Chattisgarh basin and Cuddapah basin successions occurred within a large continuous depository that covered a very extensive area of the craton. A probable correlation between successions of the Cuddapah basin and the PG Valley has recently also been indicated by SreenivasaRao(1987).

3.DISTRIBUTION OF PROTEROZOIC SUCCESSIONS IN THE PG VALLEY

The Proterozoic successions in the PG Valley occur in two NW-SE trending linear outcrop belts along the two margins of the Valley, and can be traced for about 450 km, from Khammani in the southeast to Wardha in the northwest. The central part of the Valley is occupied byGondwana rocks of late Palaeozoic-Mesozoic age that separate the Proterozoic outcrop belts. The Proterozoic rocks also occur in two small inliers that have been brought up by faults, within the Gondwana rocks. The Proterozoic rocks along the southwestern margin of the Valley unconformably overlie the Archaean basement, and are unconformably overlain by the Gondwana rocks. Along the north-eastern margin, the Proterozoic belt is bounded by two sub-parallel faults; one separates the Proterozoicsfrom the Gondwanas, and the other separates the former from the crystalline rocks of the basement complex.

4.STRATIGRAPHIC CLASSIFICATION: STATUS OF KNOWLEDGE

The stratigraphic classification of Proterozoic rocks of the PG Valley, mainly in its central and southern part, was first provided by King in 1881. He identified the sequence of Proterozoic rocks of the Valley as an unconformity-bound package between the granitic-gneis-sic rocks of the Archaean basement complex and the Upper Palaeozoic-Mesozoic Gondwana rocks, and classified it into two major stratigraphic units, separated by an angular unconformity. The lower unit was designated as Upper Transition series, whereas the upper one was designated as Sullavai series (Table 1).

FORMATIONS IN BASIN

AGE	FORMATION
Late Cretaceous	Chikiala
Jurassic	Hiatus
Late Jurassic	Kota
Rhactic	Maleri
Upper Triassic	Upper Kamthi
Middle Triasssic	Middle Kamthi
Lower Triassic	Lower Kampthi (Coal)
. Upper Permian	Barren Measure

The Upper Transition series was further divided into a lower Pakhal subdivision consisting of sandstone, shale and limestone, and an upper Albaka subdivision containing only siliciclastic rocks. The Sullavai series consists primarily of red sandstone with subordinate conglomerate. King noted that the Pakhal subdivision occurs in both northeastern and southwestern outcrop belts. The distribution of the Albaka subdivision was not specifically described, though it was indicated that the Albaka subdivision occurs only in the northeastern belt. The relationship between these two subdivisions was also not elaborated (Table 1). Both these subdivisions, however, are un-conformably .overlain by the Sullavai series. Heron (1949) designated the mixed carbonate-siliciclasticsequence of the Pakhal subdivision occurring to the north of the Godavari river as the Penganga series. The Penganga series was subsequently redefined as the Penganga Group (SreenivasaRao, 1985; Chaudhuri et al., 1989), although its relationship with the Pakhal Group had not been established.

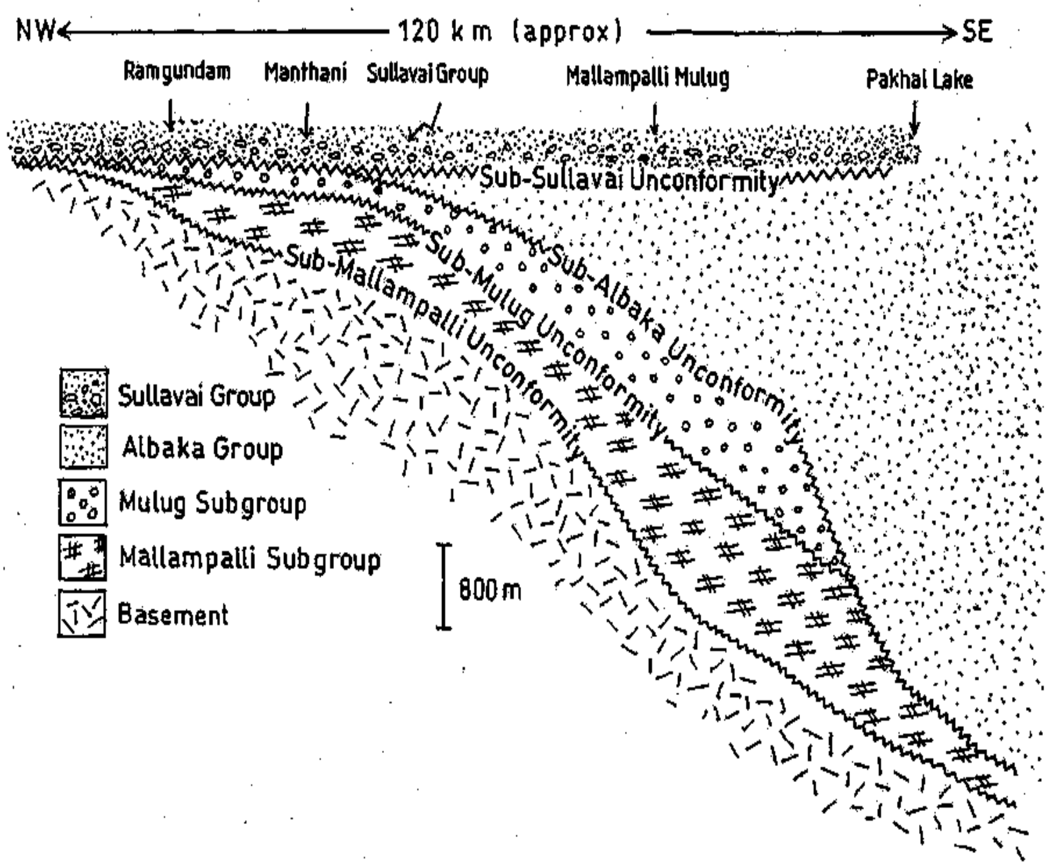

Fig: 1.Schematic diagram showing the correlation of regional unconformities in the southwestern Proterozoic belt of the PG Valley, and behavior of the

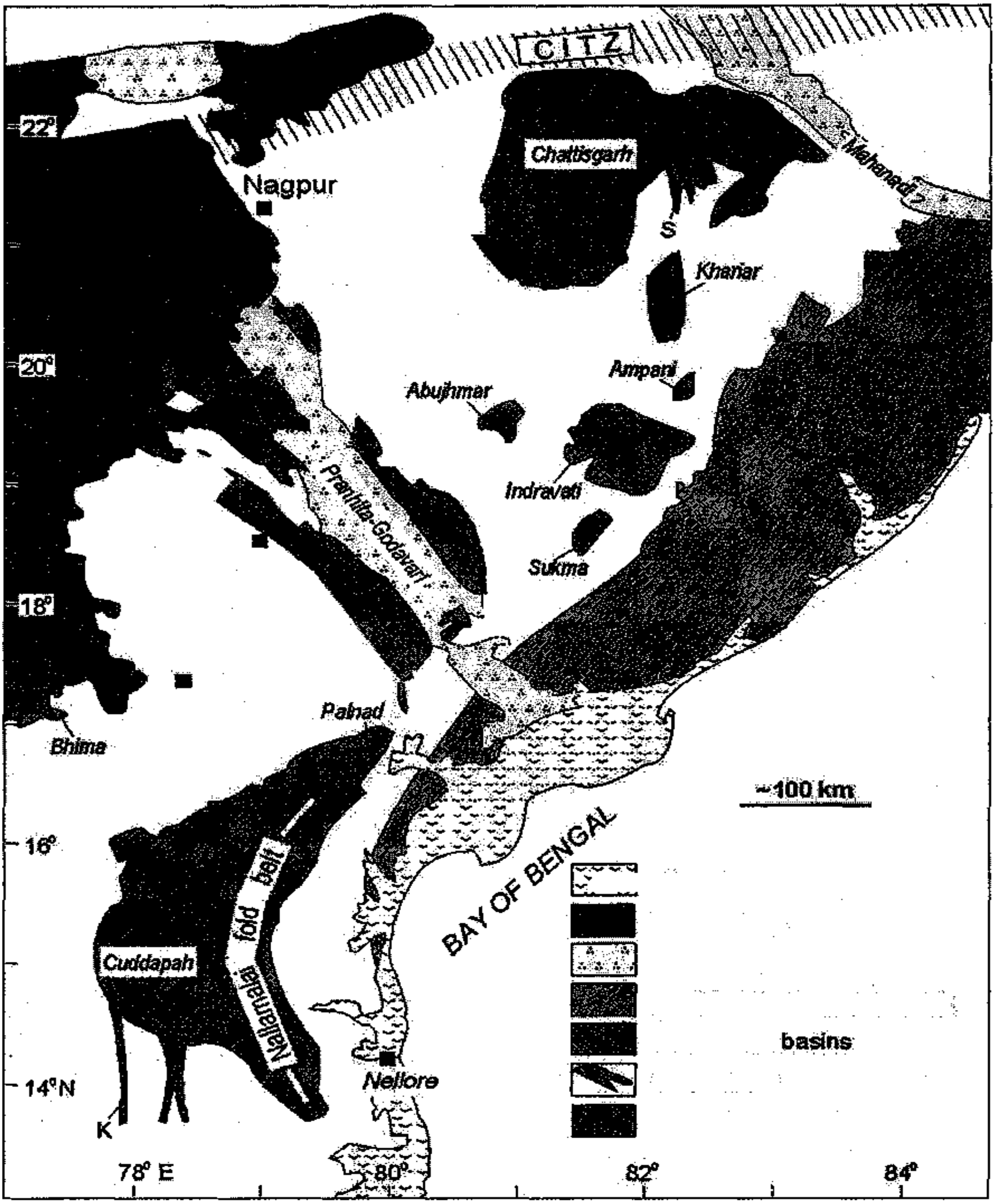

Fig: 2. Proterozoic intracratonic basins in peninsular India, south of the Central Indian tectonic zone (CITZ).

5. POTENTIAL SHALE GAS BASINS OF INDIA POSSIBILITIES AND EVALUATIONS

In pursuit of conventional Oil/Gas Exploration over the years,Geologists regarded Shales**as: Cap** rock by virtue of their impermeable nature and compactness thus acting as good seal. **Source Rock** by virtue of the richness of organic material content, its maturity ,generation potential and geographic spread over large areas

6.GAUGING SHALE GAS RESERVOIRS

- Methane in shales is generated from the transformation of organic material by bacterial(biogenic) and geo-chemical (thermogenic) processes
- The gas so generated gets stored by multiple mechanisms as free gas in micropores/micro-fractures and as adsorbed gas on the internal surfaces.
- Thus shale gas is a combination of sorbed gas and micropore gas
- The challenge in these accumulations is not of finding it BUT to exploit it commercially
- Thus it is more of technological challenge which has been met by innovative hydraulic fracturingand multi-lateral horizontal drillingtechniques.
- USA has emerged as the pioneer in developing and using this technology for commercial production of shale gas.

7.GEOLOGICAL PARAMETERS FOR SHALE GAS EVALUATION

Thickness & areal extent, Organic matter type & its richness, Thermal maturity, Mineralogy,Faults& Fractures, Gas content /Gas Storage and Adjacent water bearing Formations.

8.INDIA-LIKELY ACOLYTE OF SHALE GAS REVOLUTION

Rapidly growing Gas markets, India has high Natural Gas prices, Increasingdependency on LNG imports, Nascent CBM industry, Widening Demand-Supply gap, Rising Energy Consumption and Rising economic growth. The Pranhita-Godavari graben towards north-west. Nearly 2 km thick sedimentary section is expected within the graben. Gondwana rocks of Permo-Carboniferous to Early Cretaceous age, fluviatile to lacustrine in nature, occur In the Pranhita - Godavari Valley and continue underneath the Trap. Rocks of Precambrian age form the floor on which Gondwana sediments were deposited. Gondwana sediments of Lower Permian age consist of diamictite, conglomerates, shales, turbidites, rhythmites and coal seams. Middle Permian sediments are essentially coal free and consist of coarse sandstones and red clays. Gondwanas of upper Permian age are again coal bearing. In the Pranhita-Godavari graben, more than 5 km thick Gondwanasediments are estimated to occur. Depth indicates the maximum Gondwana thickness of 1.8 km under theTrap. Lower Triassic to Lower Jurassic formations essentially consist of alternation of red clays, sandstones and conglomerates. Sediments of Liassic age consist of thick sandstones, siltstones. silty clays, minor red clays with a prominent terrestrial limestone bed towards the base. Lower Cretaceous sediments comprise massivesandstones, conglomerates, white clays, thin coal seams and carbonaceous shales. The overlying Lameta beds consist of marine/brackish water limestones, sandstones, marls and clays. Gondwana basins are famous for their coal deposits.

9.HYDROCARBON POTENTIAL

Gondwana sediments are expected to form the main source and reservoir facies in the Pranhita-Godavari graben rift basin. Gas has been struck in the western part of the Krishna-Godavari basin at Mandapeta well in Chintalpudi Sandstone of Upper Gondwana, which is an encouraging factor for exploration in Gondwana sediments. . These gases contain high percentage of Methane (94% +) and are considered to be of thermogenic origin. Lower Gondwana sediments (Barakar Formation In particular), containing abundant organic matter, are thought to constitute good source rocks. Vitrinitereflectance studies indicate that the shale sequences are within the zone of hydrocarbon generation (Pranhita Godavari: TOC 3.58 to 6.41%, VRo 0.47 to 0.67). About 2 km thick sedimentary section is sandwiched between the Deccan Trap and the Precambrian basement in a number of depositional sequences and reservoir facies are well developed in the adjoiningPranhita-Godavari basin in both the Upper and Lower Gondwanasequences, and are expected to be present.

10.GONDWANA BASINS (PRANHITA-GODAVARI BASIN) INTRACRATONIC RIFT BASIN TRENDING WNW-ESE THREE SUB BASINS ARE IDENTIFIED:

1) EASTERN ALBAKA

2) CENTRAL PAKHAL

3) WESTERN CHANDARPUR

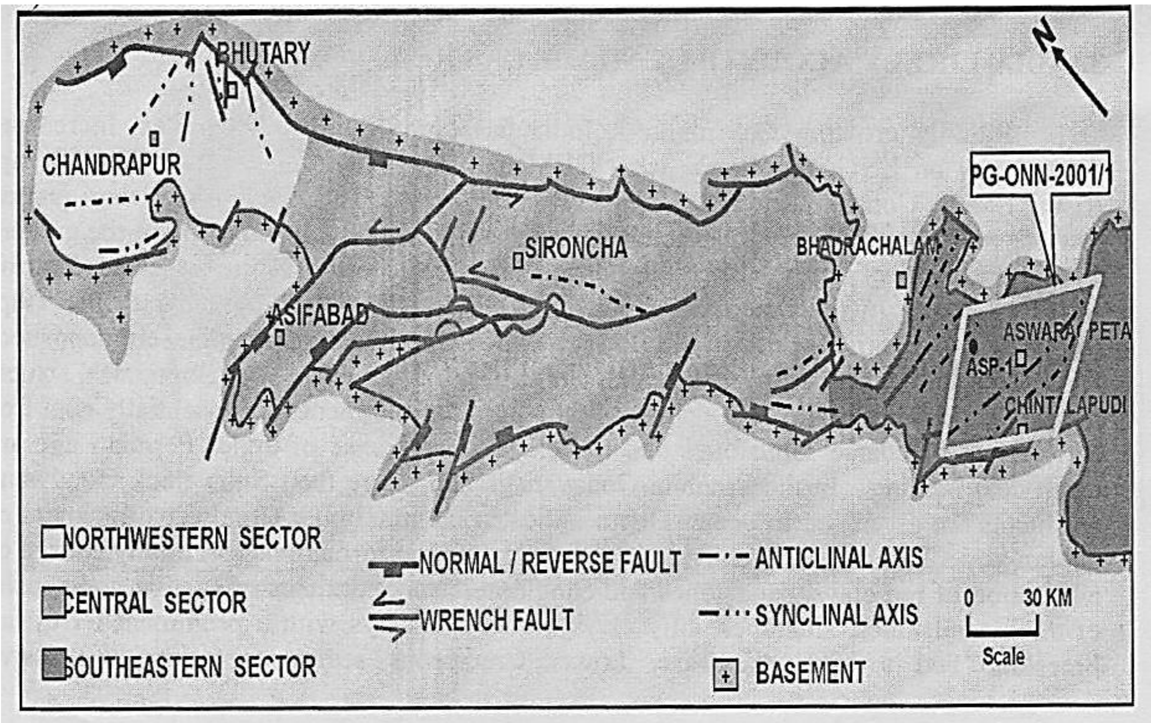

Fig: 3. Three Sub-basins of Pranhita - Godavari Basin. As per the Halliburton Guidelnes

Petroleum Potential	TOG(wt%)
Poor	0-0.5
Fair	0.5-1.0
Good	1,0-2.0
Very Good	2.0-4.0
Excellent	>4.0

Kerogen	Main expelled Product at peak .
I	Oil
II	Oil
II/III	Mixed Oil & Gas
III	Gas
IV	None

Stage of thermal Maturity	VRo %
Immature	0.2-0.6
Early Mature	0.6-0.65
Peak Mature	0.65-0.9
Late Mature	0.9-1.35
Post Mature	>1.35

SHALE CHARACTERISTICS OF PRANHITA-GODAVARI BASIN

Formation/ Group	Thickness (mt)	TOC %	VRo%	Kerogen Type
Lower Gondwana Group	400-550	3.58% - 6.41%	0.47% - 0.67	III
Upper Gondwana Group	900 - 1100	No data		

CONCLUSIONS

The Pranhita-Godavari (PG) Valley is a major repository of Proterozoic sedimentary rocks in the Indian peninsula, and is generally believed to be anintracratonic rift basin. This paper attempts to address the Basin occurs in two parallelNW-SE trending sub-basins (the western and the eastern), situated at the junction ofDharwar and Bastarcratons, and developed after amalgamation of the craton inpalaeoproterozoic. Three sub-basins are identified in this P-G basin. Generalisedlitho-stratigraphic succession of the Gondwana sediments includes Talchir, Barakar, Barrenmeasures, Kampthi (lower Gondwana group) Maleri, Kota, Gangapur and Chikialformations (upper Gondwana group). Two Proterozoic succession of the P-G supergroup are divided into four major groups, namely Mallampalli, Mulugu, Penganga andSullavai separated by three regional unconformities. The depositional environment varied from galcio-lacustrine to highly sinuous fluvial. The P-G basin is among the Indian Sedimentary basins that have been identified as having hydrocarbon potential. Twoblocks have been awarded in the basin PG-ONN-2-1/1 and GN-ON-90/3, while work inthe block GN-ON-90/3 has been held up due to the Naxalite problem for the past 13years. The block, PG-ONN-2001/1 was awarded to ONGC under the NELP-III in 2003and is the only block awarded in the P-G basin in the New Exploration Licensing Policyera. The other block, GN-ON-90/3, was awarded in the fourth round of the pre NELP erain 1993 to partners Hindustan Oil Exploration Company and Mafatlal Industries Limited(MIL). Incidentally, ONGC is also the license for this joint venture block. The delayshave set back the investigation for hydrocarbons in the under explored P-G basin by morethan 15 years. The basin covers the states of Andhra Pradesh and Maharashtra. The P-Gbasin is a potential Shale Gas basin. The Shale characteristics of P-G basin especially inthe lower Gondwana group with TOC% is 6.4%, VRo% is 0.67 and Kerogen type is III.Shale Gas exploration in India is in nascent stage, ONGC has already initiated theprocess and 1st Shale Gas exploratory well is under drilling in Bengal basin. Initiatives being taken by Government of India through Directorate General of Hydrocarbons &Ministry of Petroleum Natural Gas to have international multi task ventures is a welcomestep in this direction. We are awaiting for the 1st bid round of Shale Gas blocks proposedto be offered by MOPNG by the end of 2011.The analysis of the basin is basedessentially on the review of published records and maps, supplemented by unpublisheddata where necessary.

Oil & Natural Gas Corp. Ltd. is assessing the viability of a shale gas occurrence atits first shale research and development well in the Damodar basin northwest of Calcutta,India. Gas flowed at an undisclosed rate from the Permian Barren Measure shale at 1,700at the RNSG-1 well near Durgapur at Ichapur, West Bengal, on Jan. 25, 2011. ONGCdrilled the well to a total depth of 2,000 m and encountered the shale at985-1,843 m. ONGC said the well is India's first to produce gas from shale and the first in Asia. ONGC found many promising shale sequences in the Damodar, Cambay, Krishna- Godavari, Cauvery, Assam-Arakan, and other basins since 2006 (OGJ Online, Sept. 23, 2010). It decided to proceed in the Damodar basin because it already had coalbed methane operations there, the.shale is shallow, and water is abundant in case hydraulic fracturing is needed. The 17-month program consists of four wells, two in the Raniganjsubbasin in West Bengal and two in the North Karanpurasubbasin in Jharkhand.

Gondwana sediments are expected to form the main source and reservoir faciesin the Pranhita-Godavari graben rift basin. Gas has been struck in the western part of theKrishna-Godavari basin at Mandapeta well in Chintalpudi Sandstone of Upper Gondwana, which is an encouraging factor for exploration in Gondwana sediments. . These gases contain high percentage of Methane (94% +) and are considered to be of thermogenic origin. Lower Gondwana sediments (Barakar Formation In particular), containing abundant organic matter, are thought to constitute good source rocks. "Vitrinitereflectance studies indicate that the shale sequences are within the zone of hydrocarbon generation (Pranhita Godavari: TOC 3.58 to 6.41%, VRo 0,47 to 0.67). About 2 km thick sedimentary section is sandwiched between the Deccan Trap and the Precambrian basement in a number of depositional sequences and reservoir facies are well developed in the adjoining Pranhita-Godavari basin in both the Upper and Lower Gondwana sequences, and are expected to be present.

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