"....many ideas held validly as recently as two years ago, are now known to be false. Such is the penalty of research."

ROBERT L. FOLK (1968)

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INTRODUCTION

CHAPTER 1
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PREAMBLE

The term 'Gondwana' was proposed as 'Gondwana System' by Henry Benedict Medlicott in 1872 in an unpublished report on Satpura Basin (Holland 1926). Later, Fiestmantel (1876), while working on Damodar valley, formally introduced and established the name 'Gondwana System' for the plant bearing beds of India. Since then, over the years the term Gondwana (derived from the ancient kingdom of 'Gonds' in central India) has in Indian Stratigraphy, attained the status of 'Supergroup' and is now circumscribed to include primarily terrigenous sediments with marine interbeds ranging in age from earliest Permian to terminal Triassic including earlier Jurassic (Venkatachala and Maheshwari, 1988). Sedimentary sequence representative of Gondwana Supergroup in Indian Peninsula occurs as several isolated linear belts, most of them occupying present day river valleys within elongated depressions on the Pre-Cambrian shield (Fig.1.1a). The Pranhita-Godavari (P.G.) valley, which forms the area of the present study, is one such linear belt and is remarkably unique from other Gondwana basins of Peninsular India (e.g. Koel-Damodar, Mahanadi etc.) in that, it preserves an uninterrupted sequence of sediments ranging in age from basal Permian to early Cretaceous, the other basins being marked by a distinct Jurassic hiatus (Mitra & Raja Rao, 1987 and Sengupta 1996).

The NNW-SSE trending Pranhita-Godavari valley extends well over 470 km in strike length from Eluru on the east coast of Andhra Pradesh to Boregaon in the NW in the state of Maharashtra. Major portion of the valley lies in the state of Andhra Pradesh for about 350 km and is called as Pranhita-Godavari (P.G.) or Godavari basin, while the adjacent part further northwest, falling in the state of Maharashtra is designated as Wardha valley. The P. G. basin contains a thick pile (4000-4500 m) of sediments which can be divided lithostratigraphically into two groups-Lower Gondwana Group and Upper Gondwana Group. The present thesis deals with sedimentation and tectonics of Lower Gondwana sediments around Bellampalli, (19°04'N ; Long. 79°30'E) Andhra Pradesh in the northwestern part of the basin.

PURPOSE OF INVESTIGATION

Ever since the pioneering work of William King (1881), the Pranhita-Godavari basin has attracted the attention of a host of geologists who have, from time to time, contributed invaluable informations on general geology and stratigraphic, palaeontologic and tectonic aspects of the basin. Sedimentological studies, whatever have been done, were mainly concentrated on the Upper Gondwana rocks whose exposures cover the major portion of the basin and are better preserved than their lower counterparts. On account of poor exposures, sedimentological data of Lower Gondwana rocks in regard to sedimentation and its effect on lithofacies dispersal is very meager. Lack of information on these aspects seem to be more augmented when compared to the Damodar valley basin, where lot of similar studies have been done on coal bearing Lower Gondwana rocks. In the present thesis, studies on the surface occurrence and disposition of rocks of Lower Gondwana Group have been supplemented with a number of lithologs and core samples spread evenly over the area. Laboratory data on the lithologs and core samples in conjunction with field characteristics, have been utilised in bringing out the general sedimentation pattern and tectonic history of Lower Gondwana Group of rocks in Pranhita-Godavari basin. In addition to this, based on lithological attributes and field occurrences of different Lower Gondwana units, an attempt has been made to review the ever dwindling lithostratigraphy of Lower Group of P. G. basin in light of those of the stratotype (Damodar basin) area.

LOCATION

The area of investigation falls in the Adilabad district of A.P., north of river Godavari and west of river Pranhita, between Bellampalli and Chinnur, covering an area of about 700 sq km (Fig.1.1b). It lies between latitude 18°50'N and 19°08'N and longitude 75°25'E and 79°48'E and forms parts of Survey of India toposheet Nos. 56M/8, 56N/5, N/9 and N/13, of 1:50,000 scale.

LOGISTICS

The study area in general, exhibits flat and undulate terrains with occassional highlands. Hard sandstones belongs to Sullavai in the western part of area and near Chinnur stand out as high ridges controlling the drainage

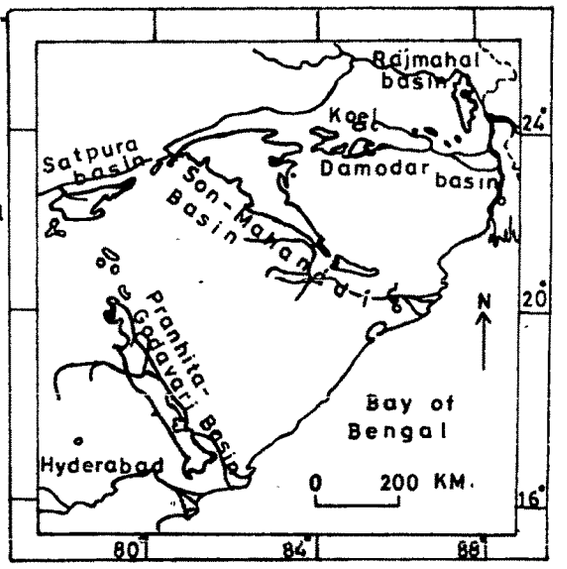

Fig.1.1a: Location map of Gondwana basins of Peninsular India

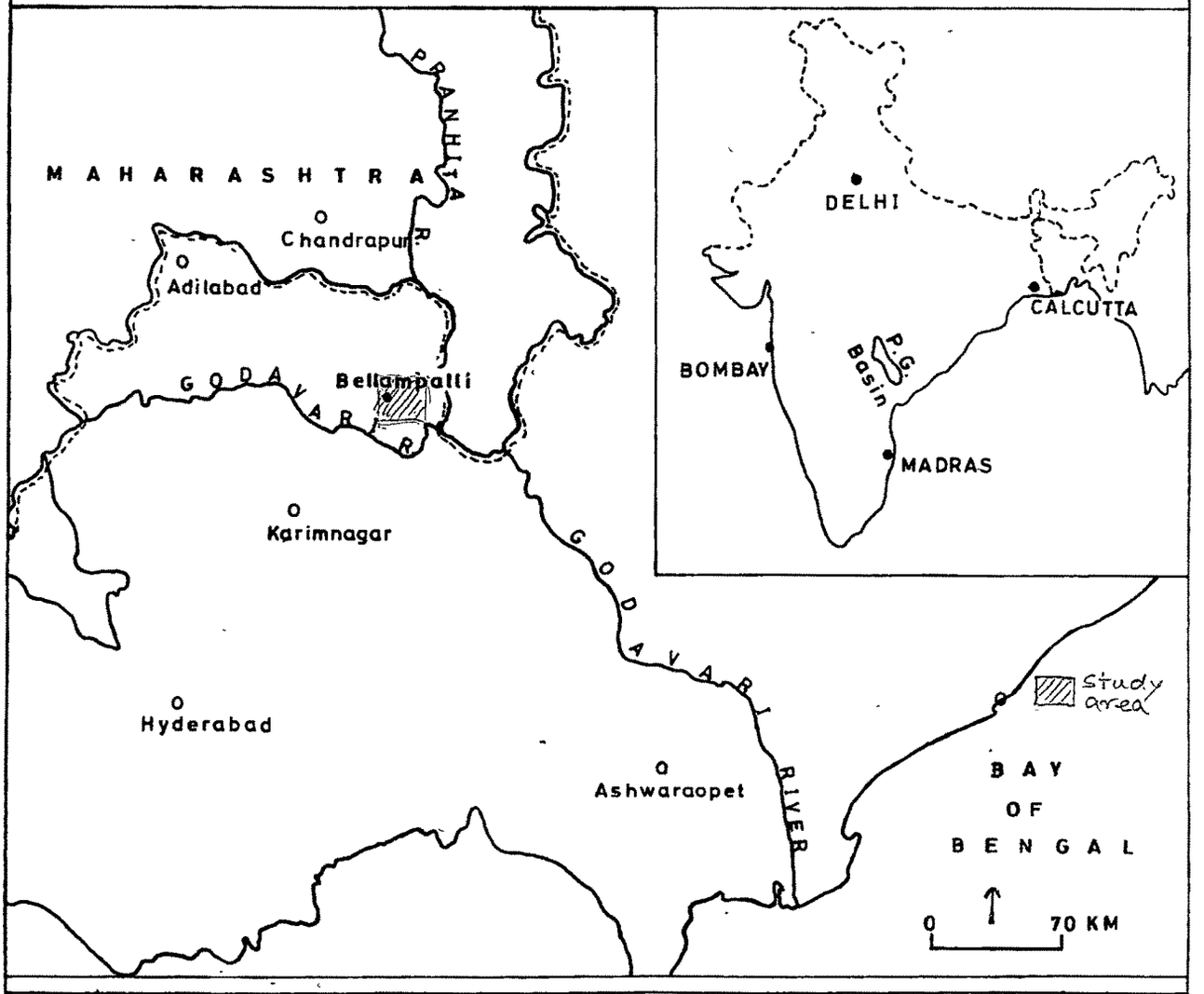

Fig.1.1b: Location map of the study area.

pattern. Plains are dissected by number of streamlets mostly flowing in south or southeasterly direction ultimately feeding the Godavari river. Sub-parallel to trellis drainage pattern is observed. Minimum temperature varies from 10°C during winter to 28°C during summer while the maximum temperature varies from 29°C during winter to 49°C during summer. Most of the area falls under Tandur, Madaram, Bellampalli, Indaram and Kundaram reserve forest. Since the last five years, there has been a spurt in the extremist (Naxalite) activity in this region.

The area is well traversed by rail and roads. Bellampalli forms a railway station on the Kazipet-Ballarshah section of South-Central (S.C.) railway. The S-C railway track and Hyderabad-Nagpur highway passes through the western part of the area. State capital Hyderabad and Adilabad district headquarters are about 280 and 180 kms. respectively from Bellampalli. Bellampalli and Chinnur, which form the two extreme ends of the study area are connected by state highway on which lie important towns like Bhimaram, Jaipuram, Indaram, Mancherial, Madnamarri and Ramkrishnapur.

AIMS AND OBJECTIVES

The aims and objectives of the study are,

- To review the lithostratigraphy of the Lower Gondwana Group of the P. G. basin in the light of existing works and the present study,
- To understand the relationship between the reviewed stratigraphic classification and the sediment characters based on texture and mineralogy.
- To bring out the diagenetic history of the Lower Gondwana rocks.
- To work out the provenance for these sediments
- To evolve the sedimentation pattern and depositional history of the sediments during various stages of Lower Gondwana time and
- To evaluate the factors controling the present day disposition of the Lower Gondwana lithofacies.

METHODS AND MATERIALS

To achieve the above objectives, selected traverses were taken covering

all litho-units of the area. The gross lithology, geometry, sedimentary structures including current structures were observed and recorded; the vertical and lateral relationship of various litho-units were traced and recorded. More than 40 lithologs were obtained from the coal companies along with 6 complete borewell samples, spread uniformly over the area.

The samples were analysed systematically in the laboratory. Textural studies of the sand samples were done with the help of granulometric analysis. Data obtained from these analyses were utilised in determining the sedimentary dynamics and evolving the depositional environment. Petrographic studies were carried out to know the mineralogy and diagenetic changes and the effect of the latter on the pore geometry of the rock. Qualitative mineralogy of the clays were estimated by using XRD. Heavies in sand samples were separated by applying gravity methods and their results were utilised in provenance study and their stratigraphic significance. Based on the lithologs and the attitude of beds, various maps such as structure contour, isopach, lithofacies maps for selected formations have been prepared to decipher the evolution of the basin during the Lower Gondwana sedimentation.

REVIEW OF LITERATURE

Literature on Indian Gondwana is voluminous **(G.S.I. No.62, 1993)** and it is an arduous task to review all the earlier works. The author, therefore, has made an attempt to present in the proceeding paragraphs a brief review of those previous works which are directly or indirectly relevant to the present study. Studies on some aspects of local importance pertaining to one or other areas have been purposefully omitted and have been referred to in the later chapters as and when required to corroborate the views and ideas expressed by the author.

STRATIGRAPHY

King (1880, 1881) was the first geologist to map the Pranhita-Godavari basin. He divided the Gondwana rocks into Lower and Upper Gondwana sequences. He further subdivided the Lower Gondwana sequence, into `Talchir', `Barakar' and `Kamthi' Group and the Upper Gondwana succession into `Maleri', `Kota' and `Chikiala' groups in the main basin and the coastal

Upper Gondwanas into `Gollapalli sandstones, `Raghavapuram shales' and `Tirupathi sandstones' in ascending order.

Based on plant remains **Oldham (1893)** and **de.P. Cotter (1917)** supported King's work of 2-foid division of Gondwanas. In addition to floras, based on vertebrate remains, **Aiyengar** and **Venkataram (1940)** divided the Gondwanas into 2 divisions. **Fox (1940)** agreed with the two fold classification and opined that the term `Middle Gondwana' in three fold classification is misleading. However, he accepted to the term `Transition series', the name given by **Fiestmantel (1875)** to indicate the horizon (in South Rewa) that petrologically exhibited an Upper Gondwana aspect but contained floral remains (*Thinfeldia*) which is of Lower Gondwana affinity.

Based on change in floral remains, **Pascoe (1959)** divided the Gondwana `system' into 2 divisions - The Lower and Upper Gondwanas, respectively characterised by *Glossopteris* and *Ptillophyllum* flora. This classification originally worked out by him in Damodar valley was extended to other Gondwana basins also.

Sahni (1963) suggested smaller subdivisions of Gondwana like Talchir, Barakar, Raniganj, Panchet etc. rather than 2-fold or 3-fold classification.

Lele (1964) classified the Gondwana Formations into three major sub-divisions on the basis of 3 floras viz. *Gangamorpteris, Dicroidium* and *Ptillophyllum* and these correspond to Permian, Triassic and Jurassic periods. His studies were, however, conducted in South Rewa Gondwana basin and it had not been subsequently correlated with other Gondwana basins of India.

Sengupta (1970) mapped the area around Bheemaram in Pranhita-Godavari basin, where he had introduced the Ironstone shales unit between Barakar and Kamthi. He adopted this name from Damodar valley.

Shah et al. (1971) proposed a biostratigraphic classification of the Indian Gondwana into Assemblage zones and Assemblage sub-zones and correlated the latter with different standard lithounits of the Gondwana Group.

Chakravarti (1974) opined that the term 'Gondwana' should be applied to a group of sedimentary rocks in Satpura basin only and not as a standard one for the whole of the country. He proposed to restrict the term 'Gondwana' only to a group of three formations viz. Pench, Motur and Bijori in Satpura basin. This group may be treated as equivalent to Damuda group in Damodar valley which consists of Barakar, Barren Measures and Raniganj formations.

Mitra, Bose and Dutta (1979) opined that periodic activations of different Gondwana grabens of Peninsular India are not isochronous phenomenon. Citing examples of discordance in different equivalent litho-units in widely separated basins, they concluded that " there seems to be no rationale for evolving a single scheme of classification for the Gondwana succession of the whole peninsular India in an all-pervasive framework".

Based on evolving flora, **Sastry et al. (1979)** supported the 3-fold divisions of Indian Gondwana and named these divisions as *Glossopeteris*, *Lepidopteris - Dicroidium* and *Ptilophyllum* assemblage zones.

Present status of Lower Gondwana stratigraphy in Pranhita-Godavari basin is due to studies conducted by **Ramamurthy (1979, 1987).** His findings, mainly based on sub-surface data, are as follows :

- occurrence of coal seam in the Kamthi Formation.
- Identification of a distinct 450 m thick non coal bearing unit between coal bearing Barakar and Kamthi Formations and naming it as Barren Measures Formation.
- Division of the newly constituted Kamthi Formation into three distinct members and correlating them with their homotaxial equivalents in Damodar Valley.

Ramanamurthy and Rao (1987) opined that the Permo-Triassic boundary in Pranhita-Godavari basin straddles through the upper part of the middle Kamthi member. Accordingly, in an attempt to maintain equivalence with Damodar Valley, they named the lower member and the lower part of the middle member as Raniganj Formation and the upper part of the middle member as Panchet Formation. In a subsequent paper, **Ramanamurthy and Rao (1996)** omitted the name 'Panchet' and renamed it as Lower Kamthi Member, the upper member being the previously named (Ramanamurthy and Rao, 1987) Kamthi

Formation.

Kutty et al. (1987) clubbed all the units between Barakar Formation and Upper Kamthi Member into a single unit and named it as Infra Kamthi which he further divided into four lithozones. The Upper Member was accordingly raised to the status of a Formation.

In a departure from the normal two-fold or three-fold classification of the Gondwanas, **Raiverman, Rao and Pal (1985)** have evolved a new stratigraphy of the Pranhita-Godavari basin by dividing the rocks of Gondwana Super group into four groups, namely Singareni, Kamthi, Sironcha and Peddavaga. Based on lithology, they have further sub-divided the groups into various formations and named them after the localities where they are best exposed.

Raju (1986) modified the four groups of Raiverman et al. (1985) to Sub-Group status with the lower two (i.e. Singareni and Kamthi) forming the Lower Gondwana Group and the upper two (i.e. Sironcha and Peddavaga) forming the Upper Gondwana Group. In naming the formations, Raju Op. cited had, more or less discarded Raiverman's Op. cited nomenclature and used the conventional names viz. Barakar, Kamthi, Maleri etc. as used by King (1881). The Barren Measures Formation is markedly absent in his classification.

Venkatachala and **Maheshwari (1988)** redefined Gondwana Supergroup for a continuous sequence of sediments laid down in peninsular India that comprises a glacigene unit at the base and red bed facies at the top represented by Talchir Group and Mahadeva Group respectively. According to them, there is a big hiatus between the red bed facies of Mahadeva Group and the overlying sediments of Rajmahal and Jabalpur Formations during the deposition of which, the basin configuration also changed.

Based on the palynological studies of borehole cores, **Srivastava** and **Jha (1989, 1990, 1992 a, 1992 b)** have concluded that the Permo-Triassic boundary in Godavari valley lies within the Kamthi Formation which forms the uppermost formation of the Lower Gondwana Group. In other words, according to them, Kamthi Formation is a time-transgressive unit. Further they suggested that the Lower and partly Middle members of Kamthi Formation are homotaxial and can be correlated with Raniganj Formation of Damodar basin.

SEDIMENTOLOGY

In one of the pioneering works on Gondwana sedimentation in Pranhita-Godavari valley (around Bhimaram), **Sengupta (1966, 1970)** stated that the different Gondwana Formations of varied sedimentological characters were contemporaneously deposited in the varied environs of the same fluvial system. Based on lithology, sand-body geometry, primary structures and patterns of grain size distribution, he, further concluded that the coarser rock units were deposited mainly by tractive currents and constituted point bars and channel bars while the finer fractions were deposited from suspension in the interchannel flood plain areas. He also suggested a northerly palaeocurrent direction for the Kamthi's.

Based on lithofacies analysis of Barakar sediments from four divisions of North-Godavari coal field, **Vijayam** and **Sarma (1971)** interpreted the control of sedimentation and dispersal of coal in each of the divisions. According to them, in each of the divisions, sedimentation was controlled by basin geometry, environment and tectonism.

On a regional scale, **Casshyap (1979)** divided the Gondwana strata into three distinct assemblages : namely the glacial deposits of Permo Carboniferous age at the base, continental fluviatile deposits ranging from Permian through Triassic and parallic to marine deposits of Lower Cretaceous age. He also discussed about the palaeodrainage and its reversals during the Late Jurassic time in various peninsular Gondwana basins.

Based on stratigraphic relationship, gross lithological attributes, mineralogical content and palaeocurrent data in the South-Central part of Godavari valley, **Rao, Raju, Khan** and **Silekar (1979)** have envisaged a northwesterly flowing braided river system as the possible fluvial model for the rocks of Gondwanas. According to them, the Pre-Cambrian gneissic complex and the Proterozoic sedimentaries at the southeastern end of the Godavari valley constituted the provenance.

Ramanamurthy (1985), Sinha and **Ramanamurthy (1979)** and **Bose** and **Ramanamurthy (1979)** have brought out wealth of data on the rocks of Lower Gondwana, south of Godavari River around Ramagundam-Mantheni area. They

have suggested as follows : i) Talchir sediments were laid down under glacial and fluvio-glacial environment and the direction of palaeocurrent was NNW and NNE. ii) Barakar and Kamthi were deposited under a laterally migrating anastomosed river system, whereas Barren Measures were laid down under braided channels. Maleris were deposited in locally developed lacustrine conditions. iii) The Eastern Ghat upland at the southern part of Godavari basin acted as provenance.

Petrographic and geochemical studies by **Sayyed** and **Patwardhan (1992)** and **Sayyed (1993)** on the Gondwana rocks (Barakar to Maleri Formations) around Adilabad and Karimnagar districts indicate that, these sediments were deposited in tectonically controlled fluctuating basin with contemporaneous upheaval and subsidence of the basin with sedimentation. They suggested that initially the environment of deposition was reducing in condition (Lower Barakar) which became gradually fresh water for younger sediments.

TECTONISM

In the IVth International Gondwana Symposium held in 1977 at Calcutta, a series of papers were presented and later (1979) published on the Tectonic evolution and frame work of the Gondwana basins of Peninsular India. While going through these papers, it becomes evident that while some authors support the rift valley concept of the Gondwana basins, some critically oppose it. Discussed below are salient points of some of these and some other papers published in other journals on tectonism of Pranhita-Godavari basin.

Dar and **Viswanathan (1964)** suggested that the Gondwana sediments were laid down in the trough faulted Cuddapah (Pakhal) basin, formed along the northwest-southwest line of weakness.

Qureshy, Brahmam, Garde and **Mathur (1968)** prepared the Bouger anomaly map and interpreted that Godavari rift valley developed along the zone of weakness, inherited from Archaean orogenesis.

Ahmad and **Ahmad (1979)** opined that faulting in Gondwana basin of India was almost subsequent to the deposition. They believed that the faulting in the Gondwana strata was due to the result of anticlockwise oroclinal rotation

of Indian landmass, which caused tension over it.

De (1979) has proposed syn-sedimentary tectonic movements in Gondwana basins of India. However in the same paper he has contradicted his earlier statement by advocating that the Gondwana grabens on Indian craton have probably been formed due to extension of crustal slab as a result of tensional force during drifting of the Indian plate in an anticlockwise direction.

Mitra, Bandyopadhyay and **Basu (1979)** opined that evolution of Godavari and Mahanadi basins was due to block movements along prominent lineaments in Pre-Cambrian rocks. These weak zones were reactivated under a neo-tensional stress regime during the Gondwana sedimentation.

Ray and **Bandyopadhyay (1979)** postulated that the three main drainage systems viz. Mahanadi-Son valley, Godavari-Narmada valley and Damodar valley drainage system are present day representatives of three major channels of ice movement which formed due to deglaciation, 300 m.y. ago. They have attributed the boundary faults in several Gondwana basins to Growth Tectonics.

K. S. Rao, T. S. Rao, Subba Raju, Khan and **Silekar (1979)** have identified four periods of rift activity in the Godavari valley along the NW-SE zone of weakness in the crystalline basement during the Pakhal, Sullavai, Lower Gondwana and Upper Gondwana times and sedimentation took place in successively developed block-faulted troughs. Gradual north-easterly shift and shrinkage in the widths of successive younger basins have been attributed by them to the recurring phases of rift activity resulting in the shifting of the site of sedimentation to the north-east and to the faster rate of basin subsidence along the eastern marginal faults.

Based on geological, geophysical and remote sensed data, **Agarwal** and **Bansal (1986)** interpreted that there had been three stages of evolution in the Pranhita Godavari graben : (i) Initiation of the protorift basin, (ii) Initiation of Permian rift and deposition of Lower Gondwana sediments, and (iii) Reactivation of north-east basin margin faults resulting in north easterly tilt and deposition of Upper Gondwanas. Further from the positive Bouger anomaly along the flanks and at some places inside the basin, they have concluded that rifting was preceeded by thermotectonic doming of the lithosphere.

Based on the presence of high density material along the Moho and in the upper crust, **Mishra, Gupta, Rao, Venkatarayudu** and **Laxman (1987)** have suggested the diapiric upwelling of the asthenosphere and subsequent block uplifting of the lower crust (which formed the shoulder of the rift) as the main causes for the evolution of typical continental graben in the Godavari valley. This was followed by intrusion of heavy material along pre-existing faults and fractures and stretching and generation of master faults towards the eastern side resulting in the extension of the region. Subsidence along the axis of graben resulted in initiation of basin formation.

According to **Casshyap** and **Tewari (1988)**, the Pranhita-Godavari and Son-Mahanadi basins which are oriented transversely to the present day east coast and whose basin boundaries are parallel to the ancient crustal lineaments, have a typical rift basin setting. The Koel-Damodar basin, according to them, however represents a crustal sag and much of the structural features there, are due to post-Gondwana faulting and erosion. Further, they emphasized that climate had an upper hand than basinal or extrabasinal tectonism on Gondwana sedimentation.

Ramanamurthy and **Parthasarathy (1988)** with the help of remote sensed data have interpreted that the Godavari basin may be divided transversely into 4 sub-basins bounded by ridges and faults. Further, they have delineated various NW-SE marginal faults and considered them as responsible for the formation of successively developed fault controlled troughs in which the Proterozoic Pakhal, Sullavai and Upper Paleozoic to Mesozoic Gondwana sediments were deposited. Based on absence of volcanism they have placed the Godavari graben in the 'Crevice' type of platform rift zone of Milonovsky (1972).

In a later paper, **Ramanamurthy (1996)** supported his earlier view and opined that block faulted movement which was initiated during Pre-Pakhal (Pre-Cambrian time) continued spasmodically till the end of Gondwana period resulting in a four stage successor type of basin evolution.

Srinivasa Rao, T., one of the co-author in **Srinivasa Rao K. et al. (1979)** paper had stated about the Proterozoic rifting in Pranhita Godavari basin. In contrast in 1987 he (single author) has ruled out any rift valley

concept for the formation of Godavari basin during Lower to Middle Proterozoic. He has stated that the eastern boundary faults were post-depositional in nature whereas the western boundary shows overlapping sequence.

According to **Chakrabarti** and **Chakrabarti (1992, 1996)** Godavari valley Gondwana basin is a gravity fault controlled rift related graben belt and its evolution can be attributed to crustal extension during Permo-Carboniferous period along the NNW-SSE trending weak zones which represent tectonic join of great antiquity between Dharawar and Bastar cratons.

Based on the contact relationship between different formations and their lithofacies character and geophysical data **Srinivasa Rao, T., (1996)** opined that the NW-SE trending mega structure of the Godavari valley is not a rift but can be designated as a raft formed by the juxtaposition of Dharwar and Bastar cratons. According to him the rafting took place after the depositon of Proterozoic sedimentaries prior to the Gondwana sedimentaiton. He suggested that the Gondwana basin developed on this raft and the Gondwana sediments were deposited pari passu with subsidence.

Lakshminarayana (1996) opined that the Gondwana tract of Pranhita-Godavari represents a 3-armed radial rift system. The NNW-SSE trending Godavari valley, which represents an aborted arm, was formed due to the rift related crustal extension and its subsequent evolution was controlled by NNW-SSE trending syn-depositional faults which resulted in the development of graben and half graben. The remaining two arms of the three arm system is occupied by the present day Krishna-Godavari coastal basin which was formed during the Early Cretaceous drifting of the Indian Plate from the Antarctic landmass.

Based on multimethod systematic gravity anomaly survey, **Murthy** and **Venkateswara Rao (1996)** suggested that the eastern boundary fault of the Godavari valley could be a junction of two microcrustal plates marked by Dharwar and Bastar cratons in the southwest and northeast respectively. According to them compressional forces causing diffential vertical movements with the Bastar craton moving upward relative to Dharwar craton might be responsible for the half-graben structure of the Godavari valley.