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SEDIMENTOLOGICAL STUDIES AND PALAEOENVIRONMENT OF LOWER GONDWANA STRATA, NORTH OF GKOC MINE, KOTHAGUDEM COALFIELDS, TELANGANA, INDIA

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ABSTRACT*:* Lower Gondwana sediments of south-central part of Pranahita-Godavari (PG) valley viz., Talchir, Barakar and Kamptee Formations were statistically analyzed for granulometry and heavy mineral assemblages. Fifteen samples were collected and analysed for granularity. Field characteristics of these litho units were used to depict the sedimentary facies which were grouped into five categories. Palaeoenvironment interpretations using granulometric data and heavy mineral assemblages showed that these sediments were deposited in a mostly fluviatile to glacio fluviatile environment sourced from a provenance of igneous and metamorphic terrain composed of granitoids, garnetiferous and micaceous schists and gneisses with moderate to moderately well-sorted sediments. By the evidence of fining upward sequences and presence of thick coal seams in the study area, it is interpreted that these sediments were deposited in a swampy and point-bar conditions of fluviatile to glacio fluviatile environment.

KEYWORDS*:* Lower Gondwana, Sedimentology, Pranahita-Godavari Valley, Kothagudem- Rudrampur, Telangana

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1. INTRODUCTION: The Lower Gondwana sediments are exposed extensively in the Pranahita- Godavari (PG) valley, over an area of 17,400 km^2 with a coal bearing area of 11,000 km^2, which are known as Kothagudem Coalfields (KCF).

In palaeoenvironmental studies of sediments, textural attributes of sediments viz. mean (Mz), Standard deviation (σ1), Skewness (Ski) and Kurtosis (KG) and heavy mineral constitution of sediments are widely used to reconstruct the depositional environments of sediments and sedimentary rocks. Correlation between size parameter and heavy mineral assemblages and transport processes/depositional mechanisms of sediments has been established by exhaustive studies from many modern and ancient sedimentary environments by many workers in the past five to six decades who have evaluated these parameters and explained their significance in relation to provenance, transportation, depositional processes and in constructing the environment of sedimentation.

Several authors have highlighted and discussed the utility of grain size analysis in the reconstruction of palaeo depositional environments and sediment dynamics. The absence of igneous intrusions indicates that the PG valley experienced a passive rift (1). In general, Lower Gondwana sediments were studied in detail than Upper Gondwana formations in terms of sedimentological studies (2). Based on different parameters like granulometry, heavy mineral assemblages and litho facies analyses, several workers have successfully interpreted the palaeo depositional history of Gondwana rocks. The Talchir Formation of Permian age is the lowermost lithostratigraphic unit of the Indian Gondwana successions preserving a record of the Late Palaeozoic glaciation that affected the whole Gondwanaland and a pro-glacial environment was inferred (3). Individual basins in different opened up, either pull-apart this art or purely rift basin depending upon the orientation of the pre-existing fracture system (4). The post-Talchir Gondwana sequence in the central PG valley consists of bands of arenaceous and argillaceous sediments of mainly fluvial origin. The onset of Gondwana sedimentation seems to have taken place on block-faulted Proterozoic basins that evolved due to repeated sagging along the north-western set and major PG lineament (5). Folk and Ward carried out extensive studies on importance of granulometry in deciphering the sedimentary environment (6). Friedman has used bivariate plots to distinguish beach and river environments (7). Freidman further studied difference in grain-size distribution of sandy sediments of different origin to elucidate palaeoenvironment [(8), (9)]. Khan and Tewari interpreted that Indian Gondwana Basins as broad intra-plate sag basins (12). The basal unit of the Gondwana Supergroup, the Permo-

Carboniferous Talchir Formation, is dominantly glaciogenic, with associated fluvial and lacustrine or marine facies demonstrating turbidite sedimentation (13). Majumdar and Ganapati have amply mentioned that grain-size analysis plays a significant role in palaeoenvironmental interpretations (14). With the retreat of the sea during 278±2 Ma (Artinkian) coeval to paroxysm of Cape Fold Belt, fluviolacustrine environment prevailed, pre-existing shear zones activated, boundary faults came into existence with response to large-scale global tectonism rendering present day landscape (16).The overlapping relationship of successive Gondwana formations of Permian and Triassic evidently indicates that initially narrow Gondwana basins at the onset of Talchir sedimentation became wider successively in Permian-Triassic is corroborated by the occurrence of Permian outcrops outside the each major basin (19). Heavy mineral assemblages in lower Gondwanas of Bellampalli area revealed a prominent igneous, medium to high grade metamorphics, a few basic and pre-existing sedimentary rocks (19). As sedimentation progressed through time, these basins expanded areally and became wider (20). The central PG valley sub-basin subsided most and shows maximum structural complexity and sediment accommodation. The rifting initiated half-graben faulting along the NE major fault and expanded by successive half-graben faulting which gave rise to intrabasinal horsts and graben which influenced the sedimentation synchronous with riftng. In the PG valley lower Gondwanaland sedimentation commenced with a pre-rift crustal sagging over the rift site and was filled with glaciogenic Talchir sediments, followed by syn-rift fluvial sedimentation in repeated cycles during the early to late rift stages (21). The fluvial cycles were not tectonically controlled during each rift stage.

The present study principally confines to the grain size and heavy mineral behavior of the Lower Gondwana sediments exposed at Rudrampur in KCF in the south-central part of the PG valley, to decipher the palaeo-depositional environment along with a broad field study of sedimentary facies. The KCF are mined and managed by the Singareni Collieries Company Ltd (SCCL).

2. STUDY AREA: The study area forms a part of 15 km long KCF, located in southern PG Valley around Kothagudem-Rudrampur and lies roughly between Long. 80^{0}30'30"E to 80^{0}41'25"E and Lat. 17^{0}27'30"N to 17^{0}31'N (Fig. I) falling in Survey of India toposheet #65C/11.

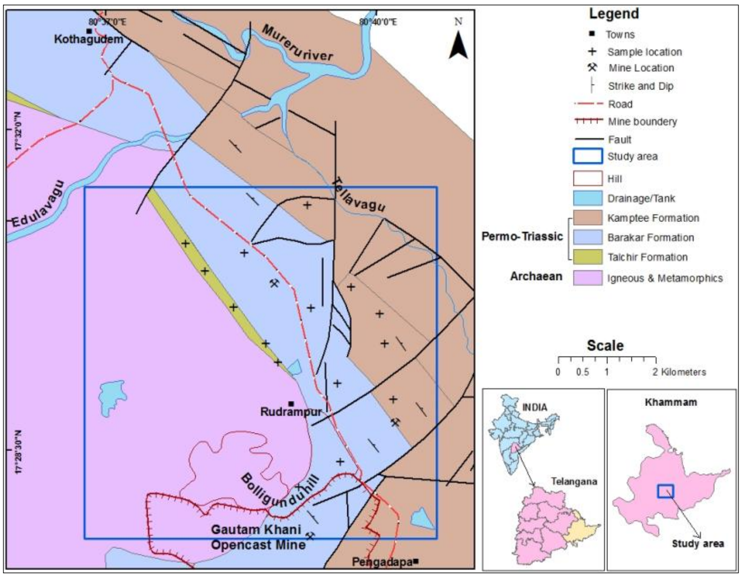


Figure I: Geological Map of the study area. (Modified after GSI, 2005 (11))

The study area lies at ~1 km north of the Gautam Khani Open-cast (GKOC) mine and 9 km SSE of Kothagudem town. The area has several inclines and shafts that actively produce coal.

3. GEOLOGICAL SETTING: In the study area lower Gondwana rocks uncoformably overlie Archaeans. The general trend of the formation is NNW-SSE. The rocks exposed in the basin belong to Talchir, Barakar and Kamptee formations (Fig. I). The Barakar Formation has a thickness of approximately 180 m in the Kothadudem are and is constituted by greyish white, very coarse to medium grained feldspathic sandstones with alternating micaceous sandstones, siltstones, grey shales, clays, carbonaceous shales and coal seams (17). Earlier the Barren Measures and Raniganj formations were grouped together as "Kamptee Formation" throughout Godavari valley Gondwana basin. Recently these formations are separately identified on the basis of lithological similarity with that of type area of Damodar valley basin (18). The age of Gondwana rocks of the study area was proposed as Asselian to Sakmarian (Permian) in Talchirs to Anisian (Triassic) in middle Kamptees (16). The coal seams are mainly interbedded and often intercalated with shale bands. The general stratigraphic succession of the study area is shown in Table I. As the Kothagudem area is a part of the ancient intra-cratonic graben, the region has suffered many tectonic disturbances. The bore-hole data revealed that this region has been affected by normal faulting both in strike and dip directions. Amongst these faults the strike faults, a number of vertical joints and minor faults have been noticed (Fig. I). There is no evidence of folding and igneous activity in the study area. The Barakar and Kamptee sandstones show a general trend of N10^{o}W to N20^{o}W with north-easterly dip. The coal seams have general trend of NW-SE direction with low dip of 10^{o}-12^{o} towards NE. Many ferrugenous concretionary structures are exposed on the bedding surfaces of the Barakars. The present distribution pattern of various geological units of this area is the net result of sedimentation, subsequent faulting and deformation, uplift and differential erosion.

Super Group	Group	Age	Formation	Lithology
Gondwana	Lower Gondwana Group	Late Permian to Early Triassic	Kamptee Formation	Conglomerate, conglomeratic sandstone, Coarse-grained ferruginous sandstone, siltstone & grey shale. Ferrugenous concretions. Gradational.
		Early Permian	Barakar Formation.	Coarse-grained, White felspathic sandstone, Siltstone, shale, carbonaceous shale and coal seams. Very coarse grained, pebbly felspathic sandstone. Gradational.
			Talchir Formation.	Fine-grained light green sandstone, green-shale, pebble beds.
Unconformity				
Kadapa	Proterozoic			Carbonate rocks.
Unconformity				
Dharwar	Archaean to Lower Proterozoic			Igneous & Metamorphic Complex comprising Dharwar Schists, granites, mafic dykes, granitoid gneiss, migmatites etc.

Table I: General stratigraphy of the study area.

4. MATERIALS & METHODS: In total, 30 samples, five each from Talchir, Bararkar and Kamptee formations for granulometry and 15 in the same horizons for heavy mineral study were collected. The analyses were carried out at a local analytical agency at Hyderabad. Samples were broken into small fragments (≥ 1cm) with a mortar and pestle taking care to avoid breaking of individual grains. The broken pieces are treated with saturated NaOH solution and concentrated HCl. After complete disaggregation, samples were oven-dried at a moderate temperature and were sieved on a Rotap sieve shaker. Grains collected on individual sieves were weighted and cumulative weight% was computed. The heavy minerals in the sample were separated from lights by using Bromoform (specific gravity 2.87). Heavy minerals are carefully separated, counted using a stereomicroscope, weighed and the percentage of each mineral category is computed. The data thus obtained was plotted and the results were used for interpretation.

5. RESULTS & DISCUSSION:

5.1 LITHOFACIES ASSEMBLAGE: During the field studies, the different lithological assemblages observed in the study area, are broadly grouped into different broad litho-facies as described hereunder which can help understanding the sedimentation history. Physical examination of the samples revealed that fresh feldspar content decreases from Talchir to Kamptee via Barakars, indicating decreasing prevalence of mechanical process.

5.1.1 TALCHIRS:

5.1.1.1. SANDSTONE FACIES: Litho-units of sandstone facies are exposed around Rudrampur trending NW-SE direction and rest unconformbaly over Archaeans. These fine to medium grained, greenish, hard and compact sandstones contain high amounts of quartz and unaltered feldspars. The feldspar and quartz grains in Talchirs are identified to have striated facets on the grain surfaces of quartz and feldspar particles reflect the transportation as the causative factor.

5.1.1.2. SHALY FACIES: Yet another facies includes green- shale beds, known as needle shales. These shales are felspathic in nature. The shales are interceded with sandstones.

5.1.2 BARAKARS:

5.1.2.1 SANDSTONE FACIES: Medium to coarse grained, occasionally fine grained, greyish to white sandstones are included in this clan. Mineralogically they contain quartz, feldspars with heavy minerals cemented with calcareous, siliceous and ferrugenous in nature. The sandstone facies show clear fining upward sequence. Cross bedding is a common feature.

5.1.2.2. FERRUGENOUS FACIES: The upper portions of Barakar sandstones are characterized by ferrugenous concretions depicting an environment dominated by reducing conditions of sedimentation along with pebble beds of varying thickness are very common. The ferrugenous concretionary beds are considered to be transitional phase of sedimentation between the Barakars and the Lower Kamptee formations.

5.1.2.3. HETEROLITHIC FACIES: A facies in which shale and sandstone occur in alternate pattern. The fine-grained, dark grey or greyish black shales are compact and occur as inseparable units within the Barakar formation.

5.1.2.4. SHALY FACIES: Dark grey shales occur as separate horizons within Barakar formations with continuous thickness. Such sections are encountered in mine sections.

5.1.2.5. COAL FACIES: Coal seams of various thicknesses occur mostly over shaly facies with sharp contact but sometimes above the heterolithic or sandstone facies. This facies grades to carbonaceous shale towards both top and below in most cases.

5.1.3 KAMPTEES

5.1.3.1. SANDSTONE FACIES: These strata occupy major portion of the Kamptees including ferrugenous sandstones, pebble beds at the bottom. These are medium to coarse grains and highly porous with ferrugenous cementing material. Rarely siliceous and calcareous cementing material is present.

5.1.3.2. FERRUGENOUS FACIES: These are sandstones with enriched ferrugenous content in the form of cementing material or as thin beds of ferrugenous material. The enriched ferrugenous nature with pyrite or altered pyrite shows prevalence of reduction conditions during sedimentation.

5.2 GRANULOMETRY AND STATISTICAL PARAMETERS: Phi value and cumulative weight percentage of the sediments is plotted on line diagram using the grain-size data (Fig. II) with cumulative data of weight percentage on the vertical arithmetic ordinate ranging from one to hundred, whereas, φ value ranges from -1.25 φ to 4.25 φ. Graphic median (φ50) is calculated using these plots (Fig. I). Most of the curves show almost similar trend, exhibiting a moderately well sorting of grains and dominance of coarse –grained sediments (10).

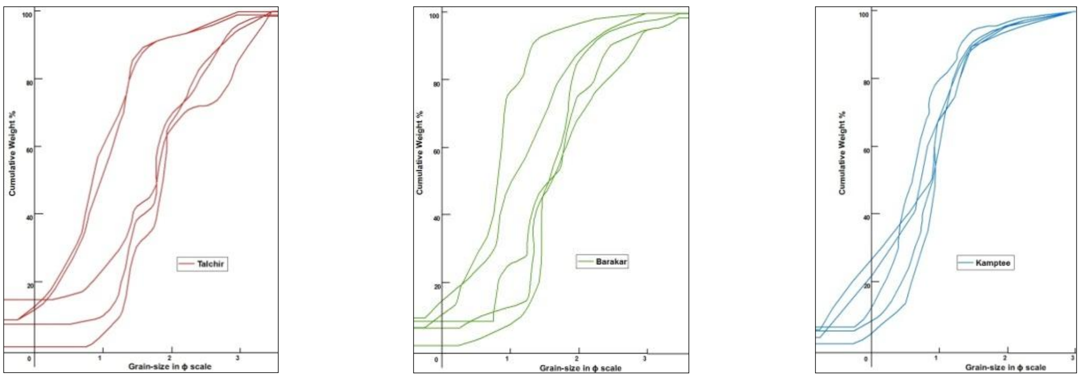


Figure II: Frequency curves of the studied samples.

Various statistical parameters obtained from statistical analysis are shown in Figure III.

5.2.1 GRAPHIC MEDIAN: Graphic median value of φ50, denoting half of the particles by weight are coarser to it and half is fine. The obtained values range from 0.9 to 1.8φ, 0.8 to 1.55φ and 0.61 to 0.85φ for Talchir, Barakar and Kamptee samples respectively. The values, in general, show the dominance of medium to coarse sand size sediments (Fig.II).

5.2.2. GRAPHIC MEAN: Graphic mean (Mz) is a measure of central tendency which is calculated by the formula φ16 + φ50 + φ83/3. The calculated values range from 0.85 to 1.88φ, 0.8 to 1.55φ and 0.61 to 0.832φ for Talchir, Barakar and Kamptee samples respectively. The results show that the major sediment class is coarse sand-size particles (Fig. III).

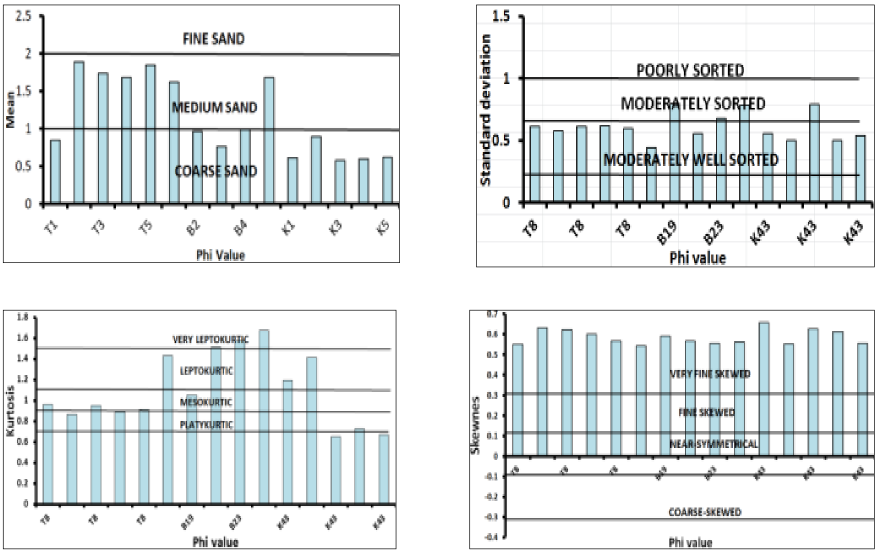


Figure III: Statistical parameters calibrated for the samples in the study area.

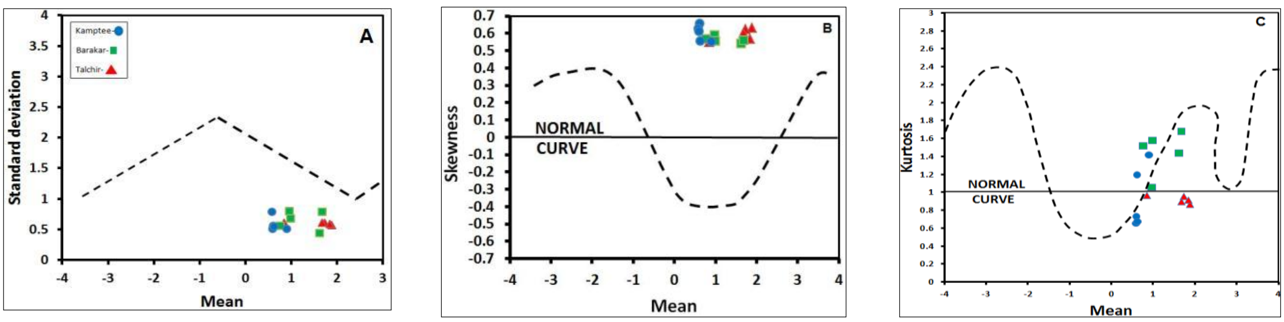
5.2.3. GRAPHIC STANDARD DEVIATION: The graphic standard deviation (σ1) is the measure of sorting or uniformity of particles size distribution and it is calculated by the formula $\varphi 84 - \varphi 16 / 4 + \varphi 95 - \varphi 5 / 6.6$. The values obtained range from 0.57 to 0.617φ, 0.44 to 0.79φ and 0.50 to 0.65φ for Talchir, Barakar and Kamptee samples respectively. Majority of the studied samples are moderately well-sorted (Fig. III).

5.2.4. GRAPHIC SKEWNESS: The graphic skewness (Sk1) measures the systematic of the distribution or predominance of coarse or fine-sediments. It is calculated by the formula $\varphi\ 84 + \varphi\ 16 - 2\varphi 50 / (\varphi\ 84 - \varphi 16) + \varphi 95 + \varphi\ 5 - 2\ \varphi 50 / (\varphi 95 - 2\ \varphi 5)$. The negative value denotes coarse-skewed material, whereas, the positive value represents more material in the fine-tail i.e. fine skewed. The skewness value ranges from 0.55 to 0.63φ, 0.54 to 0.59φ and 0.55 to 0.65φ for Talchir, Barakar and Kamptee samples respectively indicating very fine skewed (Fig. III).

5.2.5. GRAPHIC KURTOSIS: The graphic kurtosis (KG) is the peakedness of the distribution and measures the ratio between the sorting in the tails and central portion of the curve. If the tails are better sorted than the central portions, then it is termed as platykurtic, whereas, leptokurtic, if the central portion is better sorted. If both are equally sorted then mesokurtic condition prevails. The values obtained range from 0.86 to 0.96φ, 1.05 to 1.67φ and 0.65 to 1.41φ for Talchir, Barakar and Kamptee samples respectively; Talchirs are observed to have platykurtic nature, whereas Barakars are mesokurtic to very lepto kurtic and Kamptees are platykurtic to very leptokurtic nature. The very leptokurtic condition is represented by only two samples in Barakars, which is having high fraction of fine-grained sediments (Fig. III).

5.3 BIVARIATE PLOTS: Bivariate plots indicate the interrelationship of specific size parameters and are very useful to interpret pattern, mode of the sedimentation and environment of deposition (6) (Fig. IV).

The plot between mean vs. standard deviation shows the clustering of points in a narrow range of mean value on right limb of inverted V-shaped trend (Fig. IVA). It denotes a very well sorted nature and larger size range of the grains. The mean vs. skewness curve for the studied samples, denote proportionate admixture of two size classes of the sediments i.e. medium to fine sand which form a sinusoidal curve (6) falling in positively skewed area showing very fine skewed with moderately well-sorted to well-sorted nature indicating river environment (Fig. IVB). The mean vs. kurtosis plot also indicate the same result (Fig. IVC). The skewness vs. standard deviation indicates all the samples i.e. fine skewed, moderately sorted sediment falling outside the circle (Fig. IVD). The standard deviation vs. kurtosis and skewness vs. kurtosis plots show that the sediments are restricted in a narrow range of kurtosis, mostly from platykurtic to leptokurtic with very finely skewed nature, which is matching with statistical measurement. Both these plots support the conclusion already drawn on the basis of previous bivariate plots. The positive skewness indicates dominance of non-beach, mostly fluviatile system of deposition in all the studied samples (Fig. IV E& F).



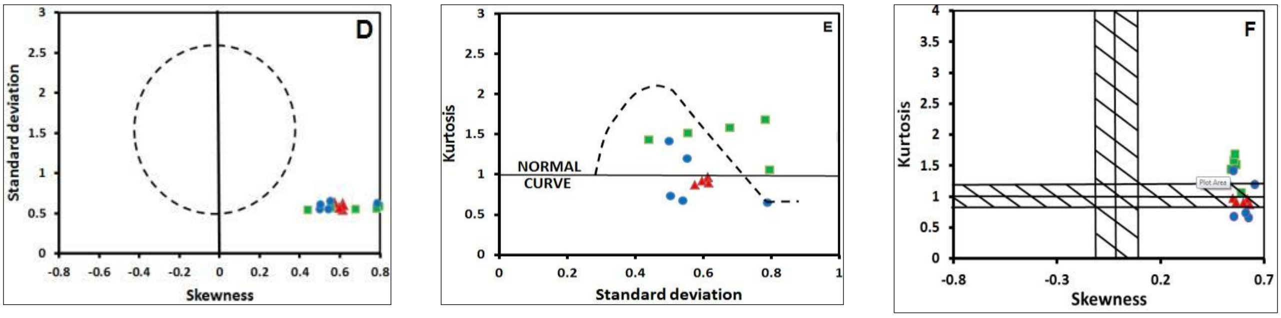


Figure IV: Bivariate plots showing the placement of present samples in the model plot (5). (A) mean vs standard deviation, (B) mean vs skewness, (C) mean vs kurtosis, (D) skewness vs standard deviation, (E) standard deviation vs kurtosis and (F) skewness vs kurtosis.

The plot between the standard deviation vs. mean and standard deviation vs skewness as proposed by Friedman and Moiola and Weiser [(7), (8), (15)] have also been attempted to cross check the results obtained (Fig. V). These plots are useful to differentiate between river and beach sediments (15). The analytical results justified the criteria of river sediments. However sample points falling in the beach field in the plot of standard deviation vs. skewness of Moiola and Weiser are due to their high mean values. From the above studies, it is evident that the sediments studied are characterized by well-sorted to moderately sorted nature, showing very fine skewed with platy/very leptokurtic nature.

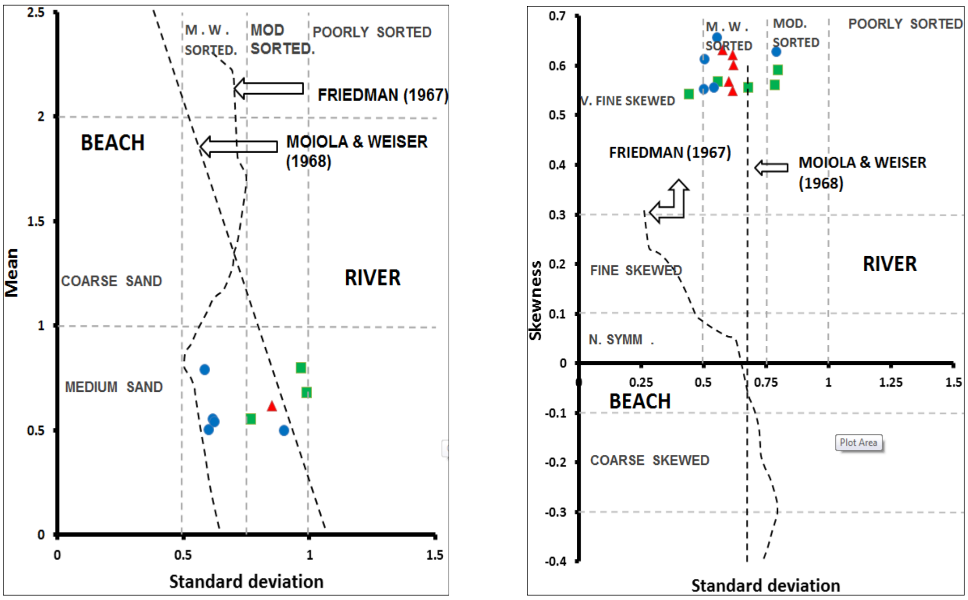


Figure V: Bivariate plots of Friedman, Moiola and Weiser for the samples.

5.4 HEAVY MINERAL STUDIES: Heavy mineral studies revealed that the samples comprise a various species viz., garnet, ilmenite, magnetite, monazite, rutile, tourmaline and zircon. Pyrite or its altered variety marcasite occurs in Kamptee sandstones in minor amounts. The average percentages of the individual heavy minerals (Fig. VI) present in all the samples has indicated certain important variations from one formation to another.

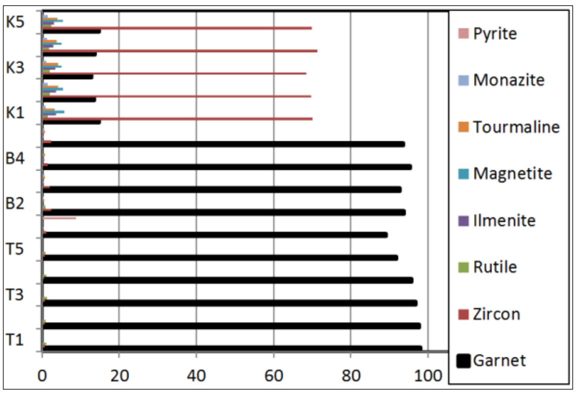


Figure VI: Heavy mineral distribution in the samples of study area.

6. PALAEO DEPOSITIONAL ENVIRONMENT: In spite of some controversies, the use of size distribution studies, for evaluating sedimentary environments, remain important tools in the field of sedimentology. On the basis of the well-known principle ‘present is the key to the past, sedimentologists have used the studies of recent sedimentary environments, to interpret the ancient environments. It can be inferred that PG Valley experienced a passive rift as the sedimentary basin is devoid of igneous intrusions (1). Using the results obtained by geological, grain-size and heavy mineral studies, following inferences can be made.

Granulometric statistical parameters show that the sediments are moderately sorted to moderately well-sorted and the coarser size and angular to sub-angular shape of the grains of quartz, feldspar etc., indicate small to moderate distance of transportation and the source rock might have been in the proximities of the depositional site. The stream and channel waters play as modes of transportation for Barakar and mainly Kamptee formations which are suggested by the presence of zircon and other heavy minerals in Kamptee, with a decrease in the garnet percentage. Fining upward sequences are observed at many places, suggesting recurring channel establishment and abandonment.

The depositional of lower Gondwana sediments in the study area has thought to be taken place in fluvial environment, as reflected by statistical calculations. The fresh feldspar content, moderately well-sorted nature, striated gravel surfaces and coarse granularity indicate a fluvio-glacial environment of Talchir sediments. During Barakar and Kamptee sedimentation, fluvial environment prevailed which is supported by low degree of grain roundness and the immaturity of sand grains, presence of sedimentary directional structures like cross stratification, increasing zircon percentages support this environment. Barakars & Kamptees register many fining upward sequences which indicate a point-bar deposit. In turn it suggests that it was deposited in a fluvial dominated condition, far away from the sea.

The physical examination of the overall lithology and mineralogical composition of Lower Gondwanas of the area suggest that the sediments might have been derived from a variety of source rock. The principal rock type which involved for the contributions of the Gondwana sedimentation of this area might be metamorphics, granites, gneisses, anothosite, quartz veins, pegmatite veins etc. Presence of kaolinite and chlorite as a cementing material indicates pore-water chemistry has influenced by climate on authigenic mineralogy of the sandstones. Talchirs and lower Kamptees are slightly enriched in chlorite indicating and arid climate causing chloritization. The felspathic nature of the cementing material in Barakars and Kamptee times, high rain-fall might be the causative factor resulting into kaolinization of felspathic material.

Garnet predominates in Talchirs and Barakars with presence of other mineral species like rutile, zircon, ilmenite, tourmaline, magnetite and monazite in traces. The conspicuous variations in the garnet and zircon content than in other mineral species is attributed to variations in the detrital influx and also basinal conditions with respect to upliftment, topography, terrain etc. The Talchir sedimentation might have been taken place in conditions where in the depositional basin was deeper which is indicated by the presence of higher garnet percentage, which has an adjacent metamorphic provenance dominantly comprised of garnet-kyanite-muscovite schists. The sediment influx in the Kamptee sandstones appears to be derived from multiple igneous sources. Presence of minor pyrite in Kamptees supports sulphide formation leading to reducing environment.

The post-Talchir deposition occurred in a well-defined fluvial system developed by broad river valleys. Presence of coarse granularity, consisting abundant fresh feldspars, and lack of coal seams and shales in the lower Barakar formation reveal the existence of a rugged source land photography and steep depositional scope at the onset of Barakar deposition (14).

The area under this study holds three to four active open-cast and underground coal mines operating in thick coal seams in Barakar strata which is a very clear evidence for the abundance of vegetative debris during the deposition and suggests a much warmer and humid climate. Coal and Carbonaceous shales represent back swamp deposits formed in tranquil water conditions during interim that period as quiescence.

CONCLUSIONS: Granulometric and heavy mineral study supplemented with field geological studies on fifteen samples revealed that the lower Gondwana sediments exposed in the study area were mostly deposited in a glacio-fluvial to fluviatile environment with moderate to moderately well sorted nature. Under the consideration of statistical analysis for the grain size parameters, the mean size of samples of the study area has rocks of coarse granularity in majority. The facies assemblages for these rocks are grouped into sandstone, shaly, heterolithic, ferrugenous, coal facies by field and physical examinations. Fining upward sequences revealed a point-bar condition of deposition. The heavy mineral assemblages showed that the sediments had a provenance of igneous and metamorphic rocks comprising granites, garnet-muscovite-kyanite schists. Presence of coal indicates back swamp deposition in much warmer and humid climate.

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REFERENCES

1. Biswas, S. K., 2003. *Regional Tectonic framework of the Pranhita-Godavari basin, India;* Journal of Asian Earth Sciences, 21, 543–551.
2. Casshyap, S.M. and Tewari, R.C., 1988. *Depositional model and tectonic evolution of Gondwana basins.* The Paleobotanists, 36, 59-66.
3. Chakraborty, C. and Ghosh, S.K., 2008. *Pattern of sedimentation during the Late Palaeozoic Gondwanaland glaciation: An example from the Talchir Formation, Satpura Gondwana basin, Central India*, Journal of Earth Systems. Science, 117 (4), 499–519.
4. Chakraborty, C. and Ghosh, S.K., and Chakraborty, T., 2003. *Depositional record of tidal flat sedimentation in the Permian coal measures of central India: Barakar Formation, Mohpani Coalfield, Satpura Gondwana basin*. Gondwana Research, 6, 817-827.
5. Das, D.P., Chakraborty, K., and Sarkar, K., 2003. *Significance of the regional lineament tectonics in the evolution of the Pranhita–Godavari sedimentary basin interpreted from the satellite data*, Journal of Asian Earth Sciences, 21 (6), 529-704.
6. Folk R. L., Ward M.C., 1957. Brazos *River bars: a study in the significance of grain size parameters*, Journal of Sedimentary Petrology, 27, 3–27.
7. Friedman, G.M., 1961. *Distinction between Dune, Beach and River sands from their textural characteristics*. Journal of Sedimentary Petrology, 31, 514-529.
8. Friedman, G.M., 1967. *Dynamic processes and statistical parameters compared for size frequency distribution of Beach and River sands*, Journal of. Sedimentary Petrology, 37, 327-354.
9. Friedman, G.M., 1979. *Difference in size distribution of populations of particles among sands of various origins*. Sedimentology, 20, 3–32.
10. Gary, M., McAfee, Jr. R. and Wolf, C.L., (Ed.), 1974. *A Glossary of Geology*; American Geological Institute, Washington D.C., 805, 1-42.
11. Geological Survey of India, 2005. *Geology and Mineral Resources of Andhra Pradesh*, Miscellaneous Publication, 30, Part III, 2nd Revised Edition.
12. Khan, Z.A., and Tewari, R.C., 2013. *Geo-statistical analysis of the Barakar cyclothems (Early Permian): A case study from the subsurface logs in Singrauli Gondwana Sub-basin of Central India*. International Journal of Geology, Earth and Environmental Science, 3 (1), 1-22.
13. Maejima, W., Nakajo, T. and Das, R., 1999. *Turbidite sedimentation in the Late Palaeozoic Talchir Gondwana basin, Orissa*, India Journal of Geosciences, Osaka City University, 42 (7), 103-114.
14. Majumdar, P. and Ganapati, S., 1998. *Grain- size frequency distribution in ancient depositional environment- a case study from Lower Gondwana sediment, Pranhita Godavari basin, Andhra Pradesh*. Journal Geological Society of India, 52, 219-228.
15. Moiola, R.J. and Weiser, D., 1968. Textural parameters: An evaluation. Journal of Sedimentary Petrology, 38 (1), 45-53.
16. Mukhopadhyay, G, Mukhopadhyay, S.K., Roychowdhury, M., Parui, P.K., 2010. *Stratigraphic Correlation between Different Gondwana Basins of India*, Journal of Geological Society of India, 76, 251-266.
17. Pascoe, E.H., 1950. *A Manual of the Geology of India and Burma*, 246-293.
18. Ramana Murty, B.V., & Madhusudana Rao, C., 1996. *A new lithostratigraphy classification of Permian (Lower Gondwana) succession of Pranhita-Godavari as in with special reference to Ramagundam Coalbelt, Andhra Pradesh, India*., Proceedings of 9th International Gondwana Symposium, Hyderabad, India, 67-78.
19. Singh, D.P., and Tewari, R.C., 2008. *Petrography and Heavy Mineral Analysis of Permian Gondwana Sandstones of Bellampalli area, Godavari Valley Coalfield, Andhra Pradesh and its Bearing on the Provenance*, Journal Indian Association of Sedimentologists, 27 (1), 93-101.
20. Tewari, R.C., 1998. *Permian Gondwana sedimentation in Yellandu (Singareni) Coalfield, Andhra Pradesh, India with notes on regional palaeogepgraphy and tectonic history*, Journal of Geological Society of India, 52, November, 569-578.
21. Tewari, R.C., and Maejima, W., 2010. *Origin of Gondwana basins of Peninsular India*, Journal of Geosciences, Osaka City University, 53 (3), 43-49.