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Grain-size variation in the River sediments: an analysis of Godavari River, India

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Abstract

In the present study, we determined grain-size variation in bed sediments of Godavari River in order to evaluate the controlling factors on grain size variation of the River sediments. Sediment samples were collected to cover the different lithological units including Deccan Volcanic Provenance (DVP), Precambrian granites/gneisses and Gondwana sedimentary rocks traversed by the Godavari River and its tributaries. The bed sediment sample of Godavari traversing DVP at Darnasangvi shows unimodal distribution of grain size but the samples from Paithan, Rakshasbhuvan, Limba and Balegoan show bimodal distribution of grain sizes. The samples from DVP show that the grains are poorly to moderately sorted with gravel percentage ranging from 53.1%-24.9%, sand from 74.7-46.6% and mud from 1.1%-0.0%. However, Paithan bed sediment collected immediately after the dam site shows different range compared to other samples as it consists of 2.7% gravel, 97.0% sand and 0.2% mud. The bed sediments of Godavari River traversing through the Deccan volcanic provenance show the positive correlation between the grain size and the weight percentage. The coarser sand and gravel are the dominant grains in the bed sediments of Godavari River traversing through DVP. This is the characteristics of the river with the lower velocity, as the velocity decreases the coarser sediments get deposited and the finer sediments will be carried by the river in suspension. The bed sediment samples of Godavari river, post-DVP, from Rangasagar, Annaram, Pusuru, Waddigudem, Rajahmundry and Yannam show unimodal distribution of grain size. The post-DVP sample from Rangasagar is very well-sorted whereas, those from Annaram, Pusuru, Waddigudem, Rajahmundry show that the grains are poorly sorted and the sample from Yannam is moderately well sorted. Gravel percentage ranges from 32.2%-0.0%, sand from 99.2%-67.4% and mud from 0.8%-0%; the Rangasagar sediment consists of 71.7% gravel, 28.3.0% sand and 0.0% mud. This distinct grain size in the Rangasagar sediment might be due to sudden change in lithology of the Godavari river from basalt to granite. Similarly, Yannam bed sediment sample also shows distinct grain size distribution: 0.0% gravel,

99.2% sand and 0.8% of mud possibly due to change in lithology from granite to sedimentary terrain. Present study reveals that flow rate of the river and bed rock lithology are the strong controls on the grain size distribution in the river sediments.

Keywords: Godavari river, sediments, grain-size, provenance, sorting.

1. Introduction

Rivers are important geological agents for erosion, transportation and deposition of sediments. A huge amount of material from continental weathering is carried by the rivers to ocean. River sediments originate from the erosion of near surface, exposed igneous, metamorphic or sedimentary rocks. Some of these are easily eroded, whereas others, especially the igneous and metamorphic rocks, are affected by streams only when altered in the surface [1]. The sediments are then deposited and may eventually be buried to produce a sedimentary rock. Some of the river sediments are deposited along the river banks referred as flood sediments. The grain size of particles in a particular deposit reflect weathering and erosion processes, with grains ranging in size from clay size particles to boulders of several meters in diameter.

In the present study, an attempt has been made to understand the grain-size variation in the Godavari River sediments in order to understand the behaviour of bed sediments derived from Deccan basalt, granite (hard rock), and sedimentary rocks. The bed sediments of Godavari River are the focus of the present study.

Geological Setting

The Godavari River also known as Dakshin Ganga is the second largest river basin with 12% of basin-drainage of India. The origin point of Godavari river is at Triambakeshwar near in Nasik (Maharashtra) and travels 1,465 km through the states of Maharashtra, Andhra Pradesh, Telangana and finally meets the Bay of Bengal in the East. The rock types traversed by the Godavari river from West to East include Deccan Volcanic Provenance (DVP), Precambrian granites/gneisses and Gondwana sedimentary rocks. The sediment discharge through Godavari river is estimated to be 170 x 10^6 t y^{-1} [2]. The Godavari river transports more than 50% of total sediment load of all tropical rivers in Southern Peninsular India. It is one of the main sources of sediments to Bay of Bengal from India after the Ganges system, and accounts 15 % of India's annual sediment budget. On the global scale Godavari River holds 9th rank in sediment transportation. The Godavari River catchment is characterized by zones of weathered and fresh rock surfaces. The drainage area in the upper reaches of Godavari river is basaltic zone, but in the lower reaches the river passes through Precambrian rocks. The prominent rock types in the study area are Deccan basalts, garnetiferous gneisses, charnockites, khondalites, granitoid gneisses and sandstones. Nearly 15% of the basin is covered by sub-tropical semi-deciduous forests [3]

2. Methodology

Sample collection

Samples were collected from the bed sediments of Godavari river. The river flows in the eastward direction and the samples were collected in dry season. The sampling locations were selected on the basis of change in lithology depending on local terrain and accessibility. Sediments samples were collected from fifteen different locations. At each location, about 3kg of sediment sample was extracted and were packed in a poly bags. Grain size analysis was done by using sieving method.

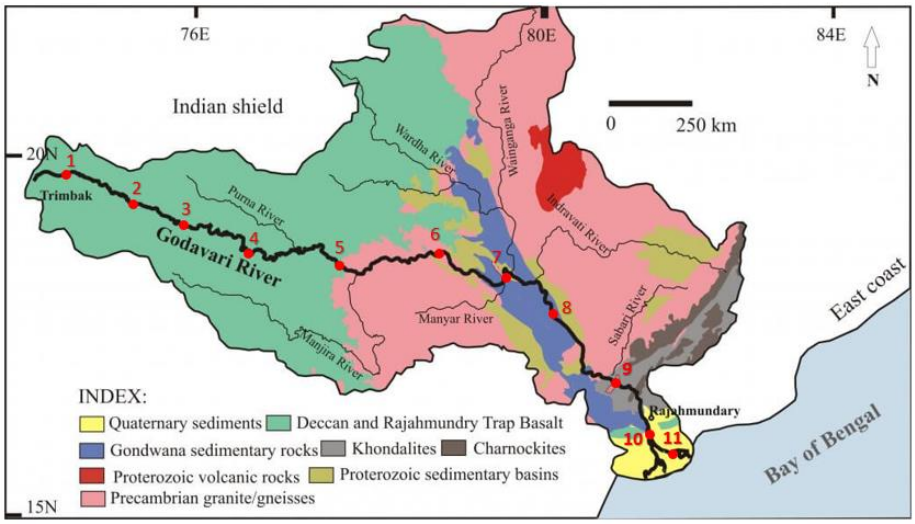


Figure: 1. Sediment sample collection sites along the Godavari River. Sketch map after [4].

Grain-Size Analysis

Grain size analysis was carried out on bed sediment samples collected along the course of the Godavari River. The analysis was carried out in School of Earth Sciences, SRTM University, Nanded. The analysis was aimed to determine the grain-size variation in sediments of the Godavari river in order to evaluate the controlling factors on the grain-size. The samples were dried prior to sieving and an electric-operated sieving machine was used to separate the sediments into different grain-sizes. Mesh sieves of 5260, 3330, 2550, 1910, 900, 610, 430, 310, 150 micron size were taken and a pan to collect extremely fine sediment. In order to characterize the sediment, we took a representative sample of a sediment and run it through a set of sieves to break the sample subset in to size classes. Set of sieves were arranged and stacked such that the screen with smallest opening is at the base and largest is at the top. Pan was place at vary base of the stack. The disaggregated samples were thoroughly mixed and split into quarters. Nearly ~1 kg of sample was inserted on to the top screen and cover with a lid. The sample was sieved for 5 minutes by setting the timer. The fraction retained in each sieve and the pan was weighed in a balance and its weight recorded and tabulated. Each sample was packed separately in poly bag. Meshes were thoroughly cleaned using blower and same procedure was repeated for all samples. Grain size data was run in Gradistat software [5]. The output of the analyses is illustrated through histograms and cumulative curves. Mean, standard deviation, skewness and kurtosis were also calculated using Gradistat software.

Mechanical analysis of sediments

In the present investigation, the inclusive graphic measures of [6] have been used to understand the grain size distribution of Godavari River.

Mean size (M_z):

The arithmetic average of grain size distribution in sediment is known as mean size and it is used to differentiate the sedimentary trends.

$$M = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

Table: 1. Grain Size: (graphic mean) [6].

Boulder	-12 to -8 phi
Cobble	-8 to -6 phi
Pebble	-6 to -2 phi
Granular	-2 to -1 phi
very coarse grain	-1 to -0.0 phi
Coarse grain	0.0 to 1.0 phi
Medium grain	1.0 to 2.0 phi
Fine grained	2.0 to 3.0 phi
Very fine grain	3.0 to 4.0 phi
Coarse silt	4.0 to 5.0 phi
medium silt	5.0 to 6.0 phi
fine silt	6.0 to 7.0 phi
very fine silt	7.0 to 8.0 phi
Clay	8.0 phi and smaller

Median:

The middle value of the grain size distribution in sediment is median.

$$Md = \phi_{50}$$

Mode:

The greatest frequency in the grain size distribution of sediment is mode.

Standard deviation (SK):

Sorting is based on at least three key variables: size range, deposition kind and current character. The grain size distribution dispersion is quantified by the standard deviation. Because it represents the energy conditions of the depositional environment but does not necessarily indicate the degree of sediment mixing, it is a crucial metric in sediment analysis [7]. It is disputed whether highly skewed sand with a moderate dispersion is better sorted than nearly symmetrical clay with a huge dispersion [8].

$$\sigma = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

Table: 2. Sorting: (From inclusive graphic standard deviation) [6].

Very well sorted	Under 0.35 phi
Well sorted	0.35 to 0.50 phi
Moderately well sorted	0.50 to 0.71 phi
Moderately sorted	0.71 to 1.0 phi
Poorly sorted	1.0 to 2.0 phi
Very poorly sorted	2.0 to 3.0 phi
Extremly poorly sorted	3.0 to 4.0 phi

Skewness (SK):

The symmetry of the grain size distribution is measured by skewness. Skewness is either positive or negative depending on whether the distribution has a tail component in the finer sizes relative to the coarser sizes. If the distribution has a tail portion in the finer sizes relative to the coarser ones, then the skewness is positive. Skewness has proven to be a useful metric for identifying different grain size distribution of sediments [6]. Skewness can be a sensitive indicator of sub population mixing, as demonstrated by [9,10], who utilized it to analyze various environments. The environmental energy was a sign of the skewness [11]. Positive skewness was associated with low energy levels (fine accumulation), whereas negative skewness was associated with high energy and sorting activity (removal of fines). Although the skewness of the grain size is very weakly correlated with other sediment parameters, its main contribution is to support [12] theory of the mixing of the fundamental populations of sand, gravel, silt, and clay.

$$Sk = \frac{\phi_{84} + \phi_{16} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_{95} + \phi_5 - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

Table: 3. Sorting Skewness: (From inclusive graphic skewness) [6].

Strongly fine skewed	+1.00 to +0.30
Fine skewed	+0.30 to +0.10
Near symmetricaal	+0.10 to 0.10
Coarse skewed	0.10 to 0.30
Strongly coarse skewed	0.30 to 1.00

Kurtosis (K):

The frequency distribution curve's degree of peakedness is measured by kurtosis, which represents the proportion of extremes to center sorting. It is a sensitive and helpful measurement for determining whether the distribution is normal. Sediments from the distribution are more accurately sorted in the middle than in the tail. The distribution is leptokurtic, or peaked in the frequency curve. When sorting in the center is almost identical to sorting in the tails, the distribution is mesokurtic. The distribution is referred to be platykurtic when the tails of the distribution are better sorted than the center region, or when the grain size frequency curve has a saddle-shaped or flat top [6,13]. According to [14], kurtosis is also seen as a measurement of the equality of two populations with various grain sizes in a combination.

$$K = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

Table: 4. Sorting Kurtosis: (From inclusive graphic kurtosis) [6].

Very platykurtic	< 0.67
Platykurtic	0.67 to 0.90
Mesokurtic	0.90 to 1.11
Leptokrutic	1.11 to 1.50
Very leptokrutic	1.50 to 3.00
Extremly leptokurtic	> 3.00

3. Results

The bed sediments samples were collected from fifteen different locations so as to understand the grain-size distribution of the Godavari Rivers. The Godavari River is traversing through the Deccan volcanic Provenance (DVP), Precambrian granites, gneiss and hard rocks such as charnockites and khondalites and finally traversing through the Precambrian and Gondwana sedimentary rocks. Here, we have shown the grain size distribution of Godavari river basin on the basis of lithology such as Godavari River on DVP and Godavari river post-DVP.

Grain Size variation of sediments while Godavari traversing DVP

1. Darnasangvi sediment sample: The Darnasangvi sample shows unimodal distribution of grain-sizes (see Fig. 2.1) and the grains are poorly sorted. The textural group is sandy gravel. The sample consists of 36.8% gravel, 62.9% sand and 0.3% mud. The mean shows that it consists of very coarse sand. The standard deviation shows that the sample is poorly sorted. It shows very fine skewed distribution and kurtosis is very platykurtic.

2. Paithan sediment sample: The Paithan sample shows unimodal distribution of grain-sizes (see Fig. 2.2) and the grains are moderately sorted. The textural group is slightly gravelly sand. The sample consists of 2.7% gravel, 97.0% sand and 0.2% mud. The mean shows that it consists of medium sand. The standard deviation shows that the sample is moderately sorted. It shows very fine skewed distribution and kurtosis is very leptokurtic. Sample shows more sand due to Dam, as coarser grains are deposited and sandy to fine sediments got transported.

3. Rakshasbhuvan sediment sample: The Rakshasbhuvan sample shows bimodal distribution of grain-sizes (see Fig. 2.3) and the grains are moderately sorted. The textural group is sandy gravel. The sample consists of 53.1% gravel, 46.6% sand and 0.3% mud. The mean shows that it consists of very coarse sand. The standard deviation shows that the sample is moderately sorted. It shows very fine skewed distribution and kurtosis is very platykurtic.

4. Limba sediment sample: The Limba sample shows bimodal distribution of grain-sizes (see Fig. 2.4) and the grains are poorly sorted. The textural group is gravelly sand. The sample consists of 24.8% gravel, 74.1% sand and 1.1% mud. The mean shows that it consists of coarse sand. The standard deviation shows that the sample is poorly sorted. It shows symmetrical skewed distribution and kurtosis is platykurtic.

5. Balegoan sediment sample: The Balegoan sample shows bimodal distribution of grain-sizes (see Fig. 2.5) and the grains are poorly sorted. The textural group is sandy gravel. The sample consists of 32.4% gravel, 67.6% sand and 0.0% mud. The mean shows that it consists of very coarse sand. The standard deviation shows that the sample is poorly sorted. It shows symmetrical distribution and kurtosis is very platykurtic.

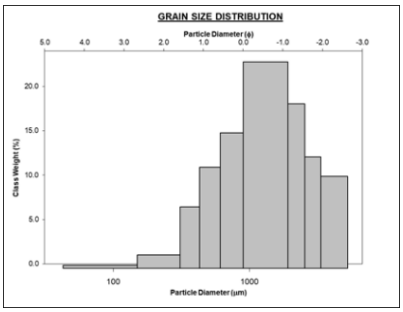
Grain Size variation of sediments while Godavari traversing post-DVP

6. Rangasagar sediment sample: The Rangasagar sample shows unimodal distribution of grain-sizes (see Fig. 2.6) and the grains are very well sorted. The textural group is sandy gravel. The sample consists of 71.7% gravel, 28.3% sand and 0.0% mud. The mean shows that it consists of very fine gravel. The standard deviation shows that the sample is very well sorted. It shows very fine skewed distribution and kurtosis is very platykurtic.

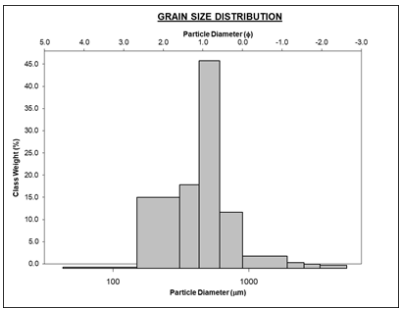
7. Annaram sediment sample: The Annaram sample shows unimodal distribution of grain-sizes (see Fig. 2.7) and the grains are poorly sorted. The textural group is sandy gravel. The sample consists of 31.6% gravel, 68.4% sand and 0.0% mud. The mean shows that it consists of very coarse sand. The standard deviation shows that the sample is poorly sorted. It shows symmetrical skewed distribution and kurtosis is mesokurtic.

8. Pusuru sediment sample: The Pusuru sample shows unimodal distribution of grain-sizes (see Fig. 2.8) and

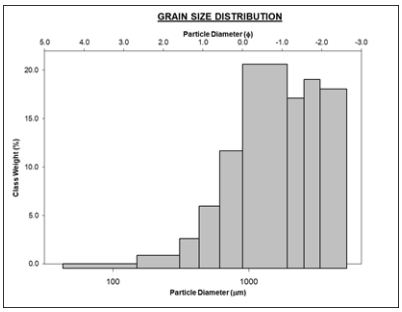
the grains are poorly sorted. The textural group is sandy gravel. The sample consists of 32.2% gravel, 67.4% sand and 0.4% mud. The mean shows that it consists of very coarse sand. The standard deviation shows that the sample is poorly sorted. It shows fine skewed distribution and kurtosis is very platykurtic.



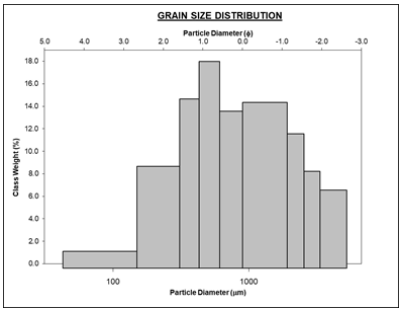
1. Darnasangvi



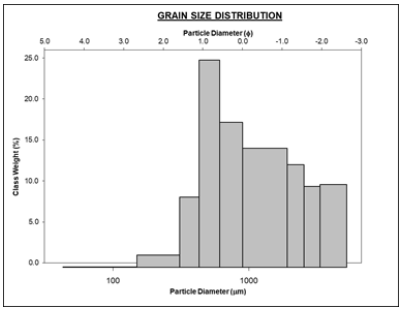
2. Paithan



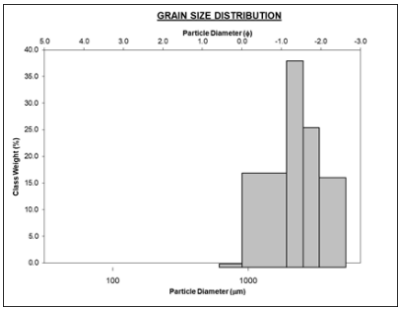
3. Rakshasbhuvan



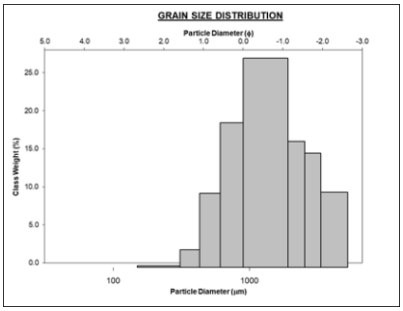
4. Limba



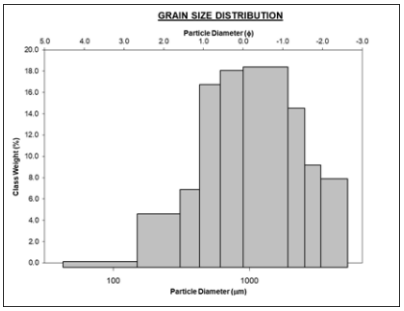
5. Balegoan



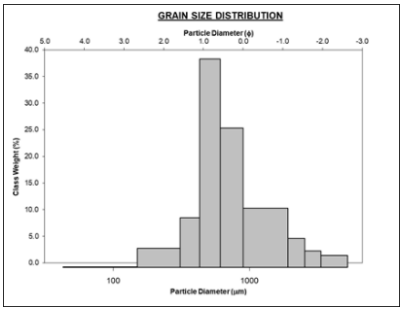
6. Rangasagar



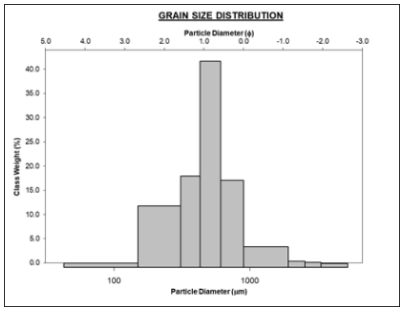
7. Annaram



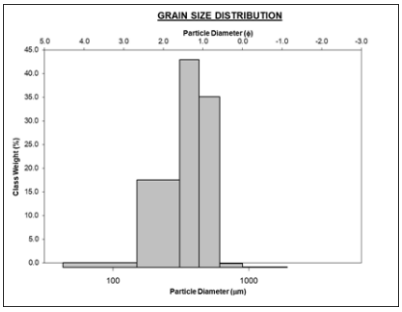
8. Pusuru



9. Waddigudem



10. Rajahmundry



11. Yannam

Figure: 2. Histographs of sediments from Godavari River.

9. Waddigudem sediment sample: The Waddigudem (after confluence of Saberi river) sample shows unimodal distribution of grain-sizes (see Fig. 2.9) and the grains are poorly sorted. The textural group is gravelly sand. The sample consists of 13.8% gravel, 86.2% sand and 0.0% mud. The mean shows that it consists of coarse sand. The standard deviation shows that the sample is poorly sorted. It shows very coarse skewed distribution and kurtosis is leptoykurtic.

10. Rajahmundry sediment sample: The Rajahmundry sample shows unimodal distribution of grain-sizes (see Fig. 2.10) and the grains are poorly sorted. The textural group is gravelly sand. The sample consists of 5.5% gravel, 93.7% sand and 0.8% mud. The mean shows that it consists of medium sand. The standard deviation shows that the sample is poorly sorted. It shows symmetrical skewed distribution and kurtosis is very leptokurtic.

11. Yannam sediment sample: The Yannam sample shows unimodal distribution of grain-sizes (see Fig. 2.11) and the grains are moderately well sorted. The textural group is sand. The sample consists of 0.0% gravel, 99.2% sand and 0.8% mud. The mean shows that it consists of medium sand. The standard deviation shows that the sample is moderately well sorted. It shows fine skewed distribution and kurtosis is platykurtic.

4. Discussion

Godavari River sediments traversing DVP

Bed sediments samples were collected from Darnasangvi, Paithan, Rakshasbhuvan, Limba and Balegoan to understand the grain-size variation while the Godavari River is traversing through Deccan Volcanic Provenance. The statistical parameters such as mean, standard deviation, skewness and kurtosis of each location are investigated. In the present study, the inclusive graphic measures of Folk and Ward (1957) have been used to understand the grain size distribution of Godavari River.

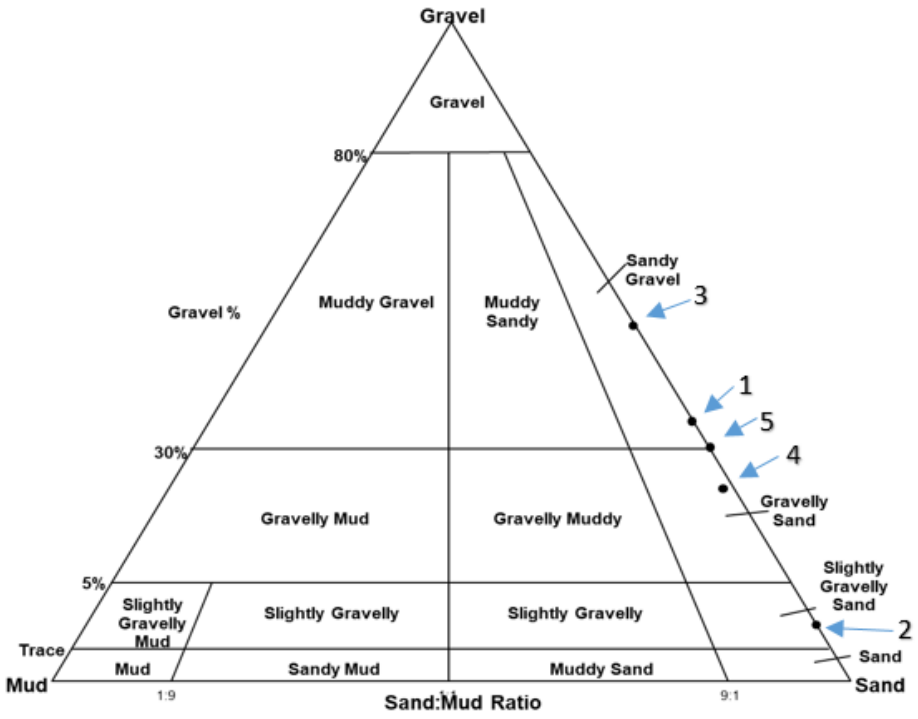


Figure: 3. Gravel-sand-mud Ternary plot for sediments traversing on DVP.
1) Darnasangvi, 2) Paithan, 3) Rakshasbhuvan, 4) Limba and 5) Balegoan.

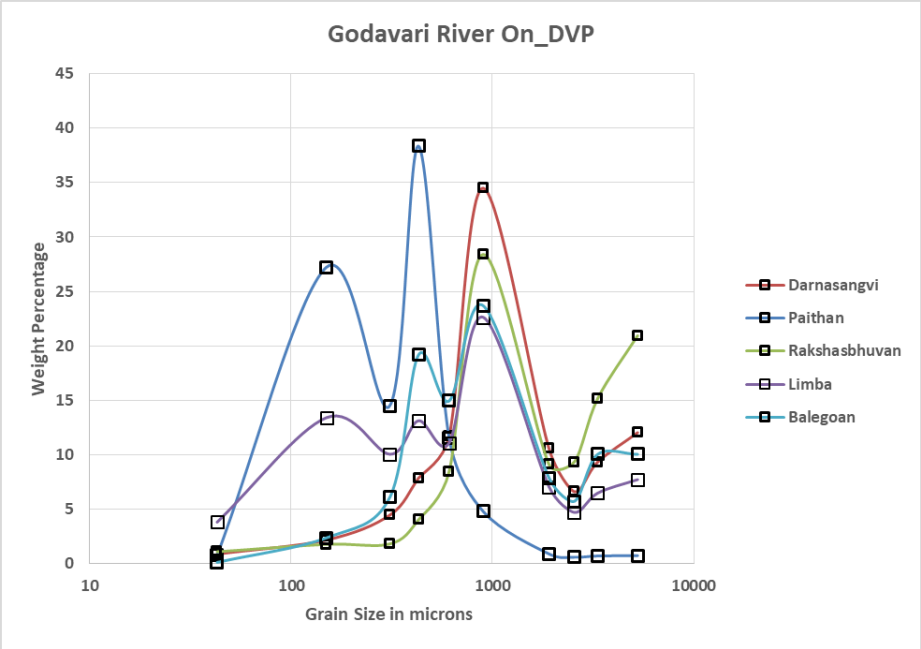


Figure: 4. The weight percentage *verus* grain size of Godavari river sediments traversing through Deccan volcanic Provenance (DVP).

The first bed sediment sample from Darnasangvi, shows unimodal distribution of grain size and the samples from Paithan, Rakshasbhuvan, Limba and Balegoan show the bimodal distribution of grain sizes. Sediments from DVP show that the grains are poorly to moderately sorted. The gravel percentage ranges from 53.1%-24.9%, sand from 74.7%-46.6% and mud from 1.1%-0.0%. Except, the Paithan, which shows extremely different range from other samples as the sample was collected after the dam site due to this only coarser grains are deposited and sand and fines have been carried away by the river.

The ternary plot of gravel, sand and mud shows that the textural group of DVP samples mainly consist of sandy gravel and gravelly sand (except Paithan sample shows slightly gravelly sand; Fig. 3). The bed sediment samples on DVP have been investigated using Folk and Ward (1957) measures and the mean of samples ranges from the maximum 0.141 phi to the minimum -0.669 phi suggesting that the grains are very coarse sand and coarse sand.

The standard deviation for the samples ranges from 1.478-0.778 suggesting that the grains are poorly to moderately sorted. The skewness for Darnasangvi, Paithan and Rakshasbhuvan are 0.277, 0.129 and 0.990 respectively, indicating finely skewed distribution; whereas, skewness for Limba and Balegoan are 0.039 and 0.022 respectively indicating symmetrical skewness. The kurtosis for all the samples ranges from 0.744-0.346 suggesting that the kurtosis is platykurtic (Paithan sample has a kurtosis value os 1.221 indicating very leptokurtic).

The bed sediments samples of Godavari River traversing through the Deccan volcanic provenance show spiked patterns in the grain size *versus* the weight percentage plots. The coarser sand and gravel are the dominant grains in the bed sediments of Godavari River traversing through DVP and the proportion continuously decreases with decreasing grain size. This is the characteristics of the river with the lower velocity, as the velocity decreases the coarser sediments get deposited and the finer sediments will be carried by the river in suspension.

Godavari River sediments traversing Post-DVP

The Godavari River after traversing through DVP, enters a terrain with Precambrian granites, gneisses of eastern Dharwar Craton, hard rocks such as charnockites and khondalites of the Proterozoic Eastern

Ghats Mobile Belt and the sedimentary rocks of Precambrian and Gondwana ages (all are considered as post-DVP). The bed sediment samples were collected from Rangasagar, Annaram, Pusuru, Waddigudem, Rajahmundry and Yannam. The total number of six different locations were selected for bed sediment samples and to understand the grain size distribution of Godavari river traversing through post-DVP. The statistical parameters such as mean, standard deviation, skewness and kurtosis of each location are investigated. In the present study, the inclusive graphic measures of Folk and Ward (1957) have been used to understand the grain size distribution of Godavari river.

The bed sediment samples from Rangasagar, Annaram, Pusuru, Waddigudem, Rajahmundry and Yannam, show unimodal distribution of grain sizes. The post-DVP sample from Rangasagar is very well sorted whereas, Annaram, Pusuru, Waddigudem, Rajahmundry show that the grains are poorly sorted and the sample from Yannam is moderately well sorted. Gravel percentage ranges from 32.2%-0.0%, sand from 99.2%-67.4% and mud from 0.8%-0.0% (except the Rangasagar, which consists of 71.7% gravel, 28.3.0% sand and 0.0% mud). The ternary plot of gravel, sand and mud shows that the textural group of post-DVP samples mainly consist of gravelly sand and sand (except Rangasagar sample, which shows sandy gravel textural group). The bed sediment samples of post-DVP have been investigated using Folk and Ward (1957) measures and the mean of samples ranges from 1.585 phi to -0.433 indicating that the grains are very coarse sand and coarse sand (except Rangasagar sample, which has the mean value -1.142 indicating very fine gravel).

The standard deviation for the samples ranges from 1.273-0.620 suggesting that the grains are poorly to moderately sorted (except Rangasagar sample with standard deviation value of 0.279 suggesting very well sorted grains).

The skewness for Annaram and Rajahmundry are -0.072 and -0.019 respectively suggesting symmetrical skewed distribution; the skewness for Pusuru and Yannam are 0.223 and 0.046 respectively indicating fine skewned distribution; whereas the skewness of Waddigudem is -0.343 suggesting the very coarse skewed distribution; and the skewness for Rangasagar is 0.279 indicating very well sorted distribution. The kurtosis for all the samples ranges from 1.509 to 0.126 indicating very platykurtic, platykurtic, mesokurtic, leptokurtic and very leptokurtic kurtosis.

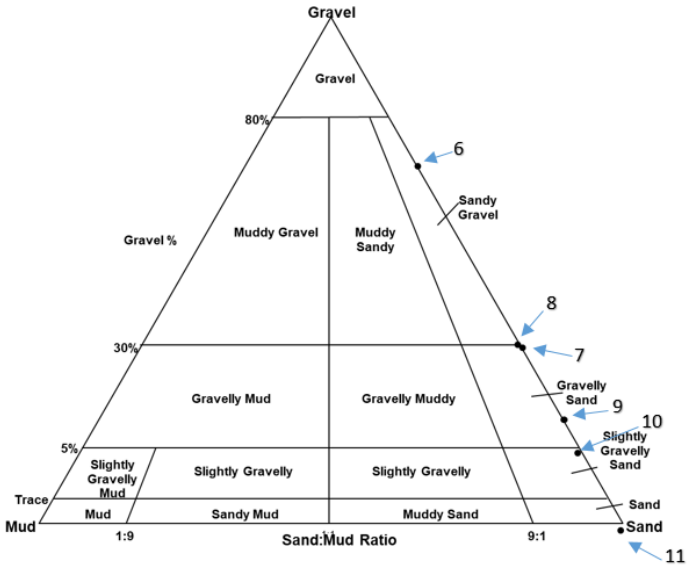


Figure: 5. Gravel-sand-mud Ternary plot for sediments traversing pos- DVP.
6) Rangasagar, 7) Annaram , 8) Pusuru, 9) Waddigudem 10) Rajahmundry and 11) Yannam.

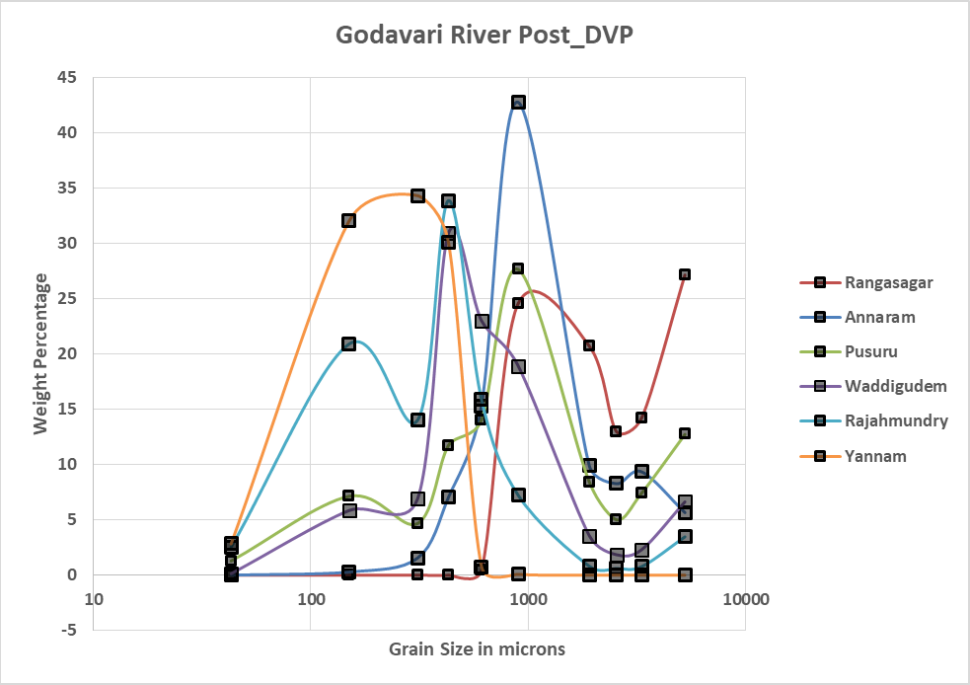


Figure: 6. The weight percentage verus grain size of Godavari river sediments traversing post-Deccan volcanic Provenance (DVP).

The Rangasagar sediment consists of 71.7% gravel, 28.30% sand and 0.0% mud. This extremely different range compared to other samples is due to sudden change in lithology of the Godavari river. From Rangasagar, Godavari begin to traverse Precambrian granites and gneisses, due to which it consists of dominantly gravel and very coarse sand. The medium to fine sand and mud are completely absent in the bed sediment sample of Rangasagar. Extremely opposite behavior of grain size distribution is seen in Yannam bed sediment sample; it consists of 0.0% gravel, 99.2% sand and 0.8% of mud. Complete absence of gravel and very coarse sand might be due to change in lithology as Godavari begins to traverse sedimentary rocks and also we can observe that the percentage of gravel is decreasing as the traveling distance of Godavari river is increasing. Similar behavior of the bed sediments samples from Annaram, Pusuru, Waddigudem and Rajahmundry are observed. At Annaram very coarse sand and coarse sand percentage is higher; As Godavari river moves downstream the medium sand and fine sand percentage begin to increase, which can be observed in Rajahmundry bed sediment sample.

5. Conclusion

we suggest that the grain-size variation in the Godavari river bed sediments is dominantly controlled by the lithology through which the river traverses.

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6. References

1. Joshua, E. O., & Oyebanjo, O. A. (2010). Grain-size and heavy mineral analysis of River Osun sediments. *Australian Journal of Basic and Applied Sciences*, *4*(3), 498-501.
2. Biksham, G., & Subramanian, V. (1988). Sediment transport of the Godavari River basin and its controlling factors. *Journal of Hydrology*, *101*(1-4), 275-290.
3. Jha, P. K., Tiwari, J., Singh, U. K., Kumar, M., & Subramanian, V. (2009). Chemical weathering and associated CO2 consumption in the Godavari river basin, India. *Chemical Geology*, *264*(1-4), 364-374.

4. Kulkarni, Y. R., Sangode, S. J., Bloemendal, J., Meshram, D. C., & Suresh, N. (2015). Mineral magnetic characterization of the Godavari River and western Bay of Bengal sediments: Implications to source to sink relations. *Journal of the Geological Society of India*, *85*, 71-78.
5. Blott, S. J., & Pye, K. (2001). GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth surface processes and Landforms*, *26*(11), 1237-1248.
6. Folk R L, W. C. (1957). A study in the significance of grain size parameters. *Journal Sedimentary Petrology*, *27*, 3-27.
7. Spencer, D. W. (1963). The interpretation of grain size distribution curves of clastic sediments. *Journal of Sedimentary Research*, *33*(1), 180-190.
8. Lewis, K. B. (1973). Sediments on the continental shelf and slope between Napier and Castlepoint, New Zealand. *New Zealand journal of marine and freshwater research*, *7*(3), 183-208.
9. Friedman, G. M. (1961). Distinction between dune, beach, and river sands from their textural characteristics. *Journal of Sedimentary Research*, *31*(4), 514-529.
10. Chappell, J. (1967). Recognizing fossil strand lines from grain-size analysis. *Journal of Sedimentary Research*, *37*(1), 157-165.
11. Duane, D. B. (1964). Significance of skewness in recent sediments, western Pamlico Sound, North Carolina. *Journal of Sedimentary Research*, *34*(4), 864-874.
12. Schlee, J. S. (1973). *Atlantic continental shelf and slope of the United States: sediment texture of the northeastern part* (No. 529-L). US Geological Survey.
13. Cadigan, R. A. (1961). Geologic interpretation of grain-size distribution measurements of Colorado plateau sedimentary rocks. *the Journal of Geology*, *69*(2), 121-144.
14. Hollister, W. M., LaPointe, A., Oman, C. M., & Tole, J. R. (1973). *Identifying and determining skill degradations of private and commercial pilots* (p. 0076). Massachusetts Institute of Technology, Measurement Systems Laboratory.