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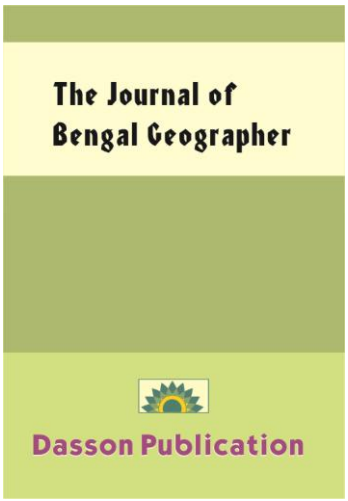

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Morphology and evolution of the Pennar river basin

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Abstract

The geomorphology is the study of formation of landforms on the earth surface through various geomorphic processes and agents envolved in their formation. The exogenetic and endogenetic processes are responsible for the formation of landforms. River basin is the land area in which the main river and its tributaries drain. Studies on geomorphology and evolution of Sarada river basin are carried out by PrudviRaju and Vaidhyanathan (1981). The evolution of landforms over the Nilagiri's of southern India are described by Parthasaradi and Vaidhyanathan (1974). Verstappen (1966) has described the role of landform classification in integrated survey. Suryanarayan (1982) has mapped the landforms of the Dharmapuri district of Tamil Nadu state and described that there is double pediplanation in the state of Tamil Nadu. Mabbutt (1966) has described the landforms of the western Mac Donnell ranges. Studies on geomorphology and evolution of major deltas of the east coast of the India are carried out by Sambasiva Rao etal (1978), Sambasiva rao and Vaidhyanathan (1979)Sambasiva Rao (1982, 2002), Kaladevi (1985) has studied the terrain characteristics, landforms and brought out the evolution of Vaigai river basin.

***Key word**: 1.Morphology, 2.Evolution and 3.Pennar river.*

Study area

The Pennar River basin covers an area about 55,213km^2 and lies in between 10^0 and 16^0 North latitude and 77^0 and 81^0 East longitude. The river originates in southeastern part of Karnataka state in Nandi hills and passes through the Anantapuramu and Cuddapah districts of Rayalaseema region and empties into Bay of Bengal, 30km ENE of Nellore after passing through the Pennar delta of Nellore district. The average annual rainfall of the Pennar basin is 732.11mm. The average minimum temperature is about 18^{0}C and the average maximum temperature is about 42^{0}C. The basin enjoys semiarid, dry sub-humid and wet sub-humid types of climate.

Objectives:

The main objectives of the present study are-
1. To describe the geology of the Pennar basin,
2. To the landforms of the Pennar basin and
3. To bring out the evolution of the Pennar basin.

Methodology:

The morphological features (landforms) of the Pennar basin are mapped through visual interpretation of IRS-IB Geo-coded data on scale 1:50,000 and FCC's on scale 1:250,000 based on tonal variations, geomorphic processes and geomorphic agents involved in the formation of landforms, alignment parallel to hilly terrain, rivers and coast, texture, shape, shade, soils and land use. Field cheeks and field traverses have been carried out to identify the photo geomorphic maps.

Geology of the pennar river basin:

Geologically the Pennar basin consists of Recent to Sub-recent alluvium gravel and sands, Late Proterozoic formations of Kurnool Group consist of Kunderu formations, Paniam formations and Jammalamadugu formations. The formations consist of Nandyala slabs, Koilakuntla limestone, Paniam quartzite, Owk slabs and Najiri limestone. There is a distinct unconformity between Late Proterozoic formations consisting of Cuddapah Super Group. It is formed of Krishna group, Nallamalai group, Chitravathi group and Papagni group. All these groups are distinguished by the presence of unconformities among them. These groups are formed of different rocks. The Krishna group is formed of Srisailam quartzite, Koilakuntla slabs and Irikonda quartzite. The Nallamalai group consists of Cumbum slabs and Bairekonda quartzite with the basic and ultra basic and igneous intrusives. The Chitravathi group is formed of Tadipatri slabs and Pulivendula quartzite with basic igneous intrusives and lava flows. The Papagni group is formed of Vempalli dolomites, slabs and Gulcheru quartzite with basic intrusive and lava flows. There is a distinct "Eparchaean unconformity" between Proterozoic formations and Archean rocks. The Archean rocks consist of dolerites, granites, felsites., pegmatite's, quartzite, peninsular gneisses, amphibolites, Phyllites and mica schist.

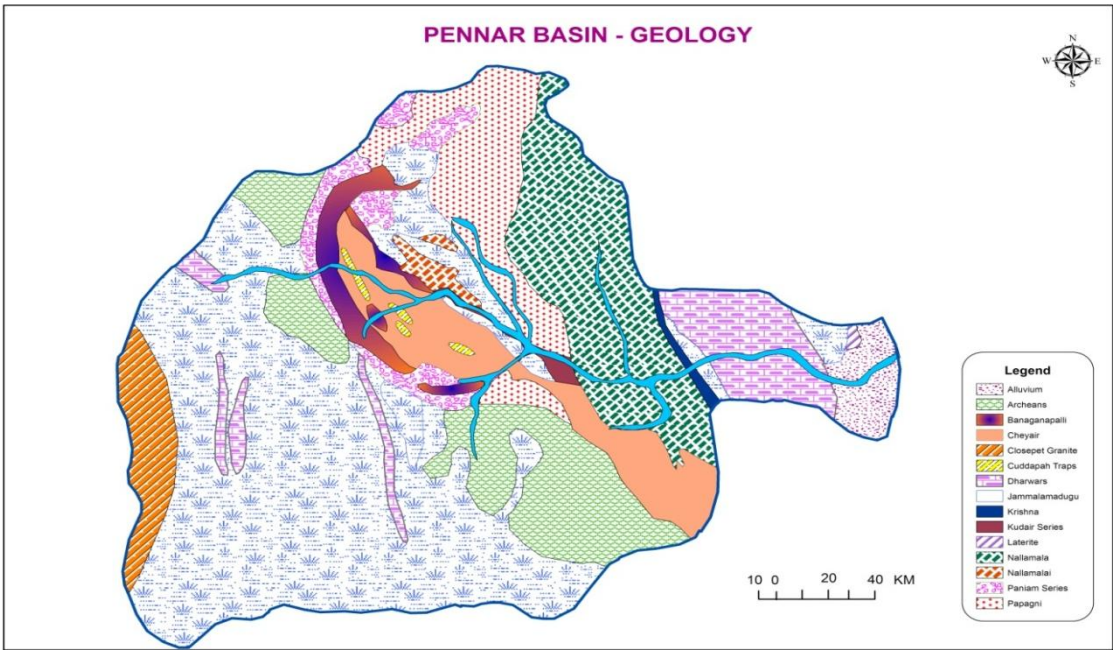

Fig.1

Archean rocks

Geographically the western, southern and southwest parts of the basin consist of Archean rocks. They are Archean rocks of metamorphic represented by gneisses, schists and granites. The Archean occupy a large part of the southern and southwestern part of the basin belonging to Kurnool, Anantapuramu and Chittoor district of Andhra Pradesh and parts of Karnataka state. Amphibolites, Peninsular chlorite schists, biotite schists, actinolite schists, hornblende granite, and quartzites represent them. The gneisses are intruded by younger granites equivalent to closet granites in the western parts of the Pennar basin. They are coarse graded gray and pink in color. The Archeans in Vajrakarur and Lattavaram are intruded by Kimberlite dykes who are diamondiferous. The Archeans are also intruded by basic dykes, which occur as elongated narrow bodies. These intrusive are mostly dolerite in nature. They are black to dark green in color, very hard and compact in nature. The Archeans of Kurnool district consist of amphibolites, hornblende schists, quartzites, phyllites, chlorite schist and mica schist. The schists are highly

folded. The composite gneisses are grey in color and show alternate banding of quartz and feldspar with those of biotite or hornblende. The granites are pink, grey and with massive, gneissic, fine to coarse grained porphyritic texture. The granites are composed of potash, feldspar, plagioclase, and quartz veins. The dykes of dolerites have intruded into the granites. The Archeans of Chittoor district covering southern and southeastern parts of the basin consist of peninsular gneissic complex with a vast spectrum of litho variations and exhibits wide variations in their external formation, and structural patterns. They range from uniformly banded gneisses of faintly foliated to homogeneous granitoids. The gneisses and associated granitites vary from white to grey in color and medium to coarse grained with variable proportions of older metamorphic enclaves. The major litho units are migmatites and associated granitoids. Amphibolites, quartz, mica schist and banded ferruginous quartzite occur as enclaves of different shapes and sizes. Swarms of dolerite, gabbro, quartz veins and reefs are intruded into these rocks of the migmatite group. Amphibolites, hornblende quartz, mica schist and ferruginous quartzites occur as enclaves and also detached bands with in migmatites.

Cuddapah super group

The rocks of Cuddapah super group mostly occupy the Nallamalai hills roughly 100 km long and 50 km width in Kurnool district. The northern and eastern parts of Atmakur, eastern parts of Nandyala and rest of Allagadda are occupied by Cuddapah formations. The Cuddapah super group belongs to Middle Proterozoic period ranging from 1100 to 1400 million years. They are divided into four groups. They are Krishna, Nallamalai, Chitravathi and Papagni. The Cuddapah super sediments are over 6000 meters in thickness. Guvvalacheru quartzite at the base and Vempalli dolomite and shales at the top resting on the Archeans represent the basal Papagni group. They are exposed over an area from north of Gooty to Dhone as a strip where it takes an easterly swing. From Bukkapuram it takes northerly bend. In Pendekal region Kurnool group of rocks overlies them. They are exposed near east of Veldurthy and extended north-northeast to east of Kurnool town. The maximum width of the strip is 10 km. The dips are gentle towards ESE. In the Veldurthy- Kalva area of the Guvvalcheruvu and Vempalli have faulted along with Chitravathi group of rocks. The faults have east, northeast and west-southwest or east-west trends. The Guvvalcheruvu formations comprise of conglomerations, quartzites, sandstones and grit with intercalated shale bands near Pyapili. The thickness here is about 60 meters. The conglomerates are polymitic and consist of rounded pebbles of granite, quartzites, chert and hematite. The quartzites are grey, red, buff, or dirty white in color. Primary structures such as ripple marks and current bedding suggests a shallow water deposition.

The Vempalli formations comprise of dolomite, shales, thin bands of limestone, quartzites, chert and chalcedony silica. The dolomites are seen in various shades of grey color. In the area north of Dhone, they have thickness of 1680 meters and near Pyapili 1130 meters. They generally form conical and rounded hills with scanty vegetation. Dolotic texture is developed in dolomites. The top of Vempalli formations is occupied by flows of basalt of andesitic composition and sills of dolerite. Barites occur with the Nallamalai group in the eastern part of district, which were subjected to intense earth movements. The dolomitic formation at places contains deposits of lead. Sills of dolerite, basalt and diorites intruded the Vempalli and Gulchaneru formations. The fractures in Vempalli form good channel ways for mineralizing fluids associated with the intrusive. Deposits of barites and steatites are associated with Vempalli dolomites. High grade limestones are also formed due to decalcification at the contact of sills and dolomites.

Chitravathi group

Overlying Papagni group of the Pulivendula quartzites and Tadipatri shales at the top, these rocks are mainly developed around Dhone, Banaganapalli areas over a narrow belt. The Pulivendula formations comprise of conglomerates and quartzites with brown, pink or grey

colors. They show shallow water deposition conditions as evidence by ripple marks and current bedding. The Tadipatri shale formations are relatively poor in limestones, quartzites and cherts. These are volcanic flows of andesitic and basaltic composition during Tadipatri period. Sills and dykes of basalt, dolerite and gabbro also intruded them.

Nallamalai group

The Nallamalai group overlying Chitravathi group consists of Bairekonda quartzite formation at the bottom and Cumbum shales at the top. Bairekonda group of rocks occupies the plains in between Nallamalai ranges and Cumbum shales in the eastern part of range, plains and hills to the east and extends beyond. Nallamalai group of rocks is highly folded and intruded by dolerites, prophyritic rocks of alkaline composition and rocks of Kimberlite composition. The Bairekonda quartzites are brown, pink, grey or greenish in color at places they are ferrugenous. They exhibit ripple marks and current bedding. The Cumbum formations comprise of shales, slates, and phyllites of variegated colors. Numerous bands of limestones and quartzites occur intercalated in them. There are bands of hematite, dolomite and chert. Quartz veins extensively traverse the Cumbum formations. At places they contain crystals of magnetite. The contact of the base of the Cuddapah's and Archean is marked by a period of hiatus known as ''Eparchaean unconformity''.

Kurnool group

The Kurnool group of rocks mainly composed of limestone and calcareous shales. They attained a thickness of 600 meters. The Kurnool group is divisible into four formations. They are Kunderu formation, Paniam formation, Jammalamadugu formation and Banaganapalli formation. The Kurnool group belongs to lower Proterozoic period ranging from 600 to 1100 million year's age.

The Banaganapalli formation consists of quartzites, sandstones and conglomerates. They are exposed at Banaganapalli, Nandavaram, Nandyala, Gani, Nandikotkur areas. They are horizontal and gentle dips. The basal conglomerate is made up of clasts of shale, chert, jasper, quartzite in a sandy or clayey matrix. Diamonds are picked up from these conglomerates. The quartzite and sandstones are medium to coarse grained and grey in color.

The Jammalamadugu group overlies the Banaganapalli formation. It comprises of Narji limestones at the base and Owk shales at the top. They are exposed of Koilakuntla, Dhone, Nandyala, Nandikotkur and Kurnool. The Najri limestones are massive and variegated in color. They are intercalated with shales and quartzite bands. They contain enormous limestone reserves.

The Paniam group of rocks comprises of plateau quartzites at the bottom and pinnacle quartzites at the top. They constitute the flat-topped ridges and plateaus to the west of Kuderu plains. The Kunderu formations are the youngest of Kurnool group comprises of Koilakuntla beds at the bottom and Nandyala shales at the top. They attain a thickness ranging from 60 to 300 meters. They are exposed in the Kunderu River, south of Allagadda to the north of Atmakur. The Koilakuntla beds consist of grey, massive, flaggy, limestones and the Nandyala shales are made up of calcareous shales and limestone.

Alluvium

Recent alluvium is deposited in the river valleys of Pennar, Chitravathi, Papagni, Cheyyeru and Kunderu. They are formed of alluvium, gravel and calcareous tufa. The alluvium formed in the modern Pennar delta is Holocene. The alluvium at the apex of the delta is boarded by sandstone lateritic uplands of Plio-miocene age. The coastal sands deposited along the coastal

plains of Pennar River are also recent and are deposited by the wave action as beach ridges and wind action as sand dunes.

Gelogical history

Geologically the Pennar basin is located in the stable shield of Indian Peninsula. The oldest rocks exposed in the basin on western, southern and southwestern parts of the group of metamorphic rocks of early Precambrian of Archean age. They comprise of quartzites, phyllites, schists, gneisses, migmatites, granites and amphibolites. These rocks have been highly folded and intruded into by granites. The composite gneisses associated with granites were formed as a result of the injection of granite, magma along weak planes in the pre-existing rocks and reaction between them. Apart from this, there are periods of erosion and non-deposition of sediments known as the Eparchean interval, ensured when there was a cessation of earth movements and igneous activity and the basin was exposed to denudation. The prolonged period of the basin formed into shallow sea. Sediments started accumulating in the Cuddapah basin. The sedimentary rocks of the Cuddapah Super Group comprises of conglomerates, quartzites, dolomites, shales, limestone and cherts. The floor of the sea was unstable and it sunk periodically. Land conditions appear to have prevailed intermittently in the basin before the deposition of the Cuddapah series there was an intermittent volcanic activity, when the lavas of the basic igneous rocks in the form of sills intruded into the Cuddapah formations. When the deposition of Cuddapah sediments ended the basin was uplifted and the strata tilted, fractured and exposed to denudation. With the passage of time the basin was again submerged beneath a shallow sea and in the Upper Precambrian and Cambrian times, the sedimentary rocks of Kurnool group comprises of limestone, shales, quartzites and conglomerates were deposited. The overlapping nature of the different formations and the lateral variation in the thickness of Kurnool strata suggest that the basin in which Kurnool sediments accumulated was unstable with frequent oscillations of the sea level. In the Post Kurnool times, the Cuddapah basin was again uplifted and the Kurnool and Cuddapah were folded, fractured and faulted then exposed to denudation.

The landforms have been categorized into denudational, fluvio-denudational, fluvial, aeolian and coastal landforms. The denudational landforms are formed of structural hills, cuesta hills, mesas, buttes, structural valleys, pediment inselberg complex, residual hills, shallow pediplains, moderately weathered pediplains and deeply weathered pediplains. The structural hills are found in Nallamalai, Palakonda, Seshachalam, Velikonda, Mutssukota and Erramalai hills. These hills are formed of Proterozoic formation consisting of shales and quartzite. The structure of the hills resembles to that of a kidney. The orientation of structural hills is north-south in Nallamalai, Velikonda and parts of Erramalai hills. The orientation is northwest-southeast and north northwest and south-southeast and east to west in Palakonda, Seshachalam and Mutssukota hills. The enclave of these hills is responsible for formation of Cuddapah basin.

The cuesta hills are found in Palakonda and Erramalai hills. These hills orient north-northwest to south-southeast in the Cuddapah basin, northwest-southeast in Palakonda hills and northeast-southwest in Erramalai hills. These hills are also formed of Proterozoic formations consisting of shales and quartzite. Mesas and buttes are found as isolated hills in the Cuddapah basin. The pediment inselberg complex is found in the granitic gneiss terrain in the western and southern parts of the basin. These are composed red sandy soils. The altitude in these complexes varies from 300 to 600 meters above MSL. The structural valleys are found in the Seshachalam, Mutssukota, Palakonda hills and in between Nallamalai and Velikonda hills (Badvel valleys) and in between Palakonda and Velikonda hills (Koduru valley). The shallow weathered pediplains are found in the granitic gneissic terrain in the southwestern parts of the basin and south of Seshachalam and Palakonda hills. The soil formation is poor and varies from 0.5 to 1 meter. The moderately weathered pediplains are found in the Cuddapah basin. They are formed of black soil

plains. The concentration of black soils is high in Kunderu valley and Tadipathri-Pulivendula basins. The soil formation is moderate. It varies from 1 to 3 meters. The soils are composed of sticky and clayey soils. The slope is less than 3 degrees. Mostly dry food crops like cotton, coriander, groundnut, bengal gram, fruits and vegetables are cultivated in these plains. Groundwater in these plains is confined to weathered fissured and fractured zones. The intensity of erosion is moderate. The deep weathered pediplains are found in Badvel and Koduru valleys in structural valleys of Palakonda and Seshachalam hills. The soil formation is good. The thickness of soils varies from 5 to 15 meters. The ground water potential is good. Groundwater is confined to weathered fissured and fractured zones.

The fluvio-denudational landforms consist of valley fills and bajadas. The valley fills are confined to Badvel and Koduru valleys. These valleys are filled up with sediments derived from bordering hilly terrain. The depth of sediments varies from 10 to 20 meters. The soil is rich and groundwater in this valley is confined to weathered fractured and fissured zones. In these soils fruits and vegetables are cultivated. In Koduru valley lemon, mango, pomegranate, papaya and orange are cultivated. The bajadas are found in the southwestern part of Koduru valley bordering the Velikonda and Thirumala hills. The soil formation is good. The bajadas are composed of deep red sandy soils. The thickness of sediments varies from 20 to 30 meters. Groundwater is confined to weathered, fissured and fractured zones. The bajadas are used for cultivation of fruits and vegetables in the Koduru valley.

The fluvial plains are composed of alluvial soils deposited in the river valley of Pennar, Chitravathi, Papagni, Cheyyeru and Kunderu rivers. These are composed mainly terraces, levees and flood plains. The thick of sediments varies from 10 to 20 meters. Groundwater is found in unconfined aquifers and groundwater recharge is high. Most of the fluvial plains are used for cultivation of paddy, banana, turmeric and betel nut. In few plains around Tadipathri guava, sapota, lemon, and pomegranate are cultivated. The sandstone lateritic uplands are found at the apex of the Pennar delta. The cashew nut and casuarinas are cultivated. The gravel is quarried from these uplands for road metal. The sandstone was formed during Mio-Pliocene period. The deltaic plains of the Pennar basin are composed of abandoned river courses, levees and flood plains. The abandoned river courses are the former river courses of the Pennar River. About seven deltaic lobes have been identified based on deposition of abandoned river courses. The levees are formed along the banks of the river Pennar formed during flood periods. They are composed of rich silt soils and rich in composition of nitrates, phosphates and potash. The coastal plains of the Pennar basin are formed in the delta front of the Pennar River along the coastline. They are formed of beach ridges, marshes, dunes, beaches and spits. The beach ridges are used for cultivation of casuriana and cashewnut. They are acting as barriers to the coastal delta front. The marshes and paleo-lagoons are composed of alkaline clayey soils. These are used for cultivation of aqua farms both for prawn culture and aquaculture along the coastal zone of Pennar delta. The sands and beaches are seen along the present shoreline. The bars and spits are formed at the confluence Point of Pennar River. In course of time they develop into barriers and enclose a lagoon behind. Later the lagoon is filled up with sediments brought by the river and converts into marshy land and finally develops into new delta front. The aeolian landforms are found in a few pockets along the major Pennar River. Due to wind action the dry sands of the river bed are migrating over the banks and develop into sand dunes and encroach rich fertile alluvial soils. The aeolian action is also found along the coastal zone in the formation of sand dunes. The sands from beaches are migrated to backshore due to wind action during low tide period and develop into sand dunes.

Morphological evolution of the pennar basin:

Geologically the Pennar basin is composed of two distinct geological formations namely Proterozoic formations consisting of shales, limestone, dolomite, with basic and ultra basic, alkaline, igneous intrusive lava flows. The Proterozoic formations consist of Kurnool group, Krishna group, Nallamalai group, Chitravathi group, and Papagni group of rocks with four distinct unconformities. The Proterozoic period extends from 600 million years to 1400 million years. The Cuddapah super group consists of Cuddapah sediments over 6000 meters thickness. The orders of sequence of sediments formations from bottom are Gulcheru quantize, Vempalli dolomites and shales of Papagni group, Pulivendula quartzites of Chitravathi group, Bairekonda quartzites and Cumbum quartzites of Krishna group. These formations belong to Middle Proterozoic period from 1100 to 1400 million years. The Late Proterozoic formations are Kurnool group. The sequence of formations of sediments from bottom is Banaganapalli formations, Jammalamadugu formations, Paniam formations and Kunderu formations. The Kurnool group of rocks is mainly composed of limestone and calcareous shales. They have attained a thickness of about 600 meters. The Late Pre-Cambrian or Archean rocks. (2400 million years) are composed of dolomite, felsites, porphysols, pegmatite and quartz vein, granites and gneisses, amphibolites, phyllites, chlorite schist and mica schists. There is a distinct Eparchean interval. There are periods of erosion and non-deposition of sediments. Geologically the older rocks exposed in the basin are a group of early Precambrian or Archean era. They comprise of quartzite, phyllites, schist gneisses, migmatites and amphipholite. These rocks are highly folded and intruded into by granites. The composite gneisses associated with granites were formed as a result of the injection of granitic magma along weak planes in the pre-existing rocks and reaction between them. Apart from this there are periods of erosion and non-deposition of sediments known as Eparchean interval, ensured when there was a cessation of earth movements and igneous activity and the basin has exposed to denudation.

This prolonged period of dormancy came to a close when in the Late Precambrian times a large tract of land in the basin formed into a shallow sea. Sediments started accumulation in the Cuddapah basin. The sedimentary rocks of Cuddapah group comprise of conglomerates, quartzites, shales, dolomite, limestone and chert. The floor of the sea was unstable and sunk periodically. Land conditions appear to have prevailed intermittently in this region before the deposition of Cuddapah sedimentation was closed. The basin was uplifted and the strata tilted, faulted fractured and exposed to denudation.

With the passages of time the Cuddapah basin was again submerged beneath a shallow sea and in the upper Precambrian and Cambrian times. The sedimentary formations of Kurnool group were deposited and later metamorphosed and mineralized to limestone, dolomites, shales, quartzites and conglomerates. The overlapping nature of different formations of Cuddapah Super Group and the lateral variations in the thickness of Kurnool strata suggest that the Cuddapah basin in which the Kurnool sediments accumulated was unstable with frequent oscillations of the sea level. In post Kurnool times the Cuddapah basin was again uplifted and the Kurnool and Cuddapah formations were folded, faulted, tilted and then exposed to denudation.

Morphologically and structurally the orientation of hills is north-south, northwest- southeast, north-northwest, south-southeast, east-west and northeast-southwest. They depict that the hills in the Cuddapah basin are subjected to folding and faulting during the Proterozoic periods of uplift. The intrusive of dykes consisting of dolerites and gabbro in the granitic terrain along weaker zones depict igneous activity. The barite mineralization in the form of veins is confined to the upper horizons of Vempalli formation comprising of dolomite, limestone, chert and chert braccica. Barites occur as bedded and massive type in Pullampeta of the Cuddapah Super Group in Obulavari palli, Cuddapah, Pulivendula, Badvel and Rajampeta mandals. These veins of pipes

were formed due to volcanic activity. Similarly the Kimberlite pipes consisting of diamonds between Vajrakarur and Lattavaram were also formed due to volcanic activity. The formations of gold in Dharwanian schists in a linear direction from north-south over a length of 11 km and with a width of 1.5 km depict intrusive activity in the basin.

The vast pediplains formation in the western, southern and central part of the Cuddapah basin varying from shallow weathered to deeply weathered zones depict that the basin has been subjected to rapidly denudation. The altitudinal variations among pediplains also indicate double pediplanation in the western, southern and central parts of the basin. Similarly there are altitudinal variations among the hills. The intensity of weathering also varies from Archean to Proterozoic formations. The Archean rocks are highly weathered, denuded and intruded by a number of dykes. The formation of dykes in east-west, north south, northeast-southwest and southern part of the basin depict that the basin has been subjected to high igneous activity. The altitudinal variations among the hills and pediplains depict that there could be five denudational levels. They are less than 150-300 meters, 300-600 meters, 600-900 meters and above 900 meters.

The Pennar delta lies on the eastern part of the basin and covers an area of about 2,700km^2. The delta is bordered by Plio-Miocene sandstone lateritic upland which is formed due to fluvial, aeolian and marine action. The delta is formed of Quaternary sediments consisting of mainly alluvial soils. The depth of alluvial sediments varies from 500 to 2500 meters. The delta is formed of older river courses, paleo confluences, natural levees, deltaic plains, beach ridges, paleo lagoons, marshes, tidal flats, sand dunes, beaches, bars and sprits. A group of old channels in an ancient river course is considered to represent major abandoned distributaries that debouched into the sea during certain period of the growth of delta. Based on disposition of ancient channels about twelve meander lobes have been delineated with twelve abandoned paleo confluences. Two abandoned meander courses are found in first stage of the growth of the delta. These abandoned distributaries debouched into northern and southern part as finger foot delta. In the second stage of the delta two abandoned meander lobes are found. In the third stage of the growth of the delta three abandoned meander lobes are found. The northeastern, eastern and southern part of the delta is dominated by fluvial processes. (Sambasiva Rao and Lakshmi Narayana 2007).

The ancient beach ridges are formed in different locations away from the present shoreline. The first series of beach ridges are found 35 km away from the shoreline at an altitude of about 10.7 meters above MSL. The second series of the beach ridges are located 22 km away from present shoreline. They are 4 to 5 in number and vary in altitude from 5.5 to 7.5 meters above MSL. Their orientation is north to south and NNW to SSE and the width is 3.5 km. The third series of beach ridges are found 10 km away from present shoreline. The altitude varies from 5.4 to 6.5 meters above MSL. Their orientation is north to south, NNE-SSW and NNW to SSE. The fourth series of beach ridges lie from present shoreline upto 3.7 km. They vary in number from 5 to 8. The altitude varies from 2.2 to 3.5 meters above MSL. The fourth series of beach ridge lie parallel to the present shoreline.

Based on deposition of abandoned meander lobes and ancient beach ridges the evolution of the modern Pennar delta has been traced by Sambasiva Rao and Lakshmi Narayana (2007). Four stand lines have been identified based on orientation, location and altitudinal variation among the beach ridges. The present rate of growth of delta is 4.46 km per thousand years. Based on c14 dating of mollascan shells present beneath the first series of beach ridges it is summarized that they have been formed around 6,500 + 500 years B.P. The second series of beach ridges might have formed around 4020+150 years B.P. The third series of beach ridges might

have formed 3050+200 years B.P. and the fourth series of beach ridges around 2100+150 years B.P. (Sambasiva Rao and Lakshminaraya 2007).

Raju and Vidyanathan (1981) made an attempt to study the evolution is Sarada River basin based on disposition of morphological features and concluded that cymatogenic upwarp, climatic changes, sea level changes, weathering, geomorphic processes and agents are responsible for the development of Sarada River basin. It is presumed that the up-liftment of the Eastern Ghats was much older than Western Ghats which might have been formed of during the Mesozoic period. After the up-liftment of the Eastern Ghats there is development of relief and drainage. Subsequent uplifts have let to faulting and folding during Tertiary period. Due to endogenetic activities faulting and folding a number of fractures might have developed due to cymantogenetic uplift. Differential weathering, mass wasting and erosional processes led to the development of valleys and low lands. The various stages in the development of the river valleys are valley deepening, valley widening, and valley lengthening. Due to the prevailing humid climate the fluvial process dominated on the process of valley deepening, valley widening and valley lengthening. Various erosional processes like hydraulic action, abrasion, corrosion, friction, cavitations and corrosion have led to the erosion of bed of the river and streams to go down. However such lowering of channel is not a continuous process. Each stream adjusts varying conditions of discharge and load for the development of slopes and gradients. Gentle gradients are formed in response to decreased energy demands. Rivers cut down to their base level constantly adjusting to the detailed morphology of their beds. As they do so, in order to maintain the equilibrium between available load and energy deepning of the river valleys seems to be mainly controlled by both exogenetic and endogenetic processes. The exogenetic processes like back weathering, gravitational activity and head ward erosion might have been responsible for the lengthening of the river valleys. Structural activities seem to the more responsible for formation of the basins and valleys in the Pennar basin. Changes in the climate, sea levels aided with geomorphic processes and agents are responsible for the development of Pennar river basin. The occurrence of fluvial terraces indicates local climate changes. Sudden changes in climate might have resulted in the changes of the river basins leading to widening and development of fluvial plains and formation of deltaic plains in the downstream. The altitudinal variations in the hilly terrain depict that there could be five denudational levels in the basin. The geological history reveals the development of pediplains due to back wasting, gravitational activity and head ward erosion. The Nallamalai, Erramalai, Seshachalam, Palakonda, Velikonda and Thirumala hills were uplifted during Proterozoic period. Subsequent upwarps led to development of folding and faulting in the formation structural hills in the Cuddapah basin. The sediments of the Cuddapah basin are slowly metamorphosed and mineralized due to compression and changes in the temperature. The Kunderu and Badvel valleys are also formed due to back weathering; gravitational activity and head ward erosion. The Pennar delta located on the eastern part of the Nellore in an area of about 2700 km^2 might have been formed during Tertiary and Quaternary periods. The modern delta sediments are presumed to have been formed during Quaternary and Holocene periods. Finally it is concluded that the Pennar basin might have been formed due to cymatogenic upwarp, climatic changes, changes in sea level, differential weathering, exo-genetic and endo-genetic processes erosion and deposition are responsible for the development.

Conclusions

The Five denudational levels have been delineated by superimposition of profiles taken in east-west direction. There is double pediplanation. The evaluation of the Pennar delta has been brought out based on disposition of abandoned meander lobes and strandlines. The geological history reveals the development of pediplains due to back wasting, gravitational activity and headward erosion. The Nallamalai, Erramalai, Seshachalam, Palakonda, Velikonda and

Thirumala hills were uplifted during Proterozoic period. Subsequent upwarps led to development of folding and faulting in the formation structural hills in the Cuddapah basin. The sediments of the Cuddapah basin are slowly metamorphosed and mineralized due to compression and changes in the temperature. The Kunderu and Badvel valleys are also formed due to back weathering; gravitational activity and head ward erosion. The Pennar delta located on the eastern part of the Nellore in an area of about 2700 km^2 might have been formed during Tertiary and Quaternary periods. The modern delta sediments are presumed to have been formed during Quaternary and Holocene periods. Finally it is concluded that the Pennar basin might have been formed due to cymatogenic upwarp, climatic changes, changes in sea level, differential weathering, exo-genetic and endo-genetic processes, erosion and deposition.

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