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Geoinformatics technique in mapping of lithology and geomorphological landforms in precambrian rocks of Kollegal Shear Zone (KSZ), southern Karnataka, India

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Abstract: Geoinformatics technique are the essential tool in mapping of lithology, geomorphology, drainage, lineament, soil, slope and other related features of a region. The present study aims to map the geology, lithological contacts, weathered layered and geomorphological landforms in Precambrian hard rock terrain of Kollegal Shear Zone (KSZ) which belongs to Dharwar Craton, adjacent to high grade granulites of Biligiri-Rangan hills in Southern India. Geoinformatics encompass Survey of India (SoI) Toposheet, Remote Sensing (RS) Satellite data, Geographic Information Systems (GIS) and Global Positioning System (GPS) with limited ground truth check. Efforts have been made to evaluate the thematic maps such as lithology, geomorphology, weathered layered, drainage, lineament, soil types, slope categories are derived using False Color Composite (FCC) data of IRS-1D PAN+LISS-III. Slope and drainage maps are derived from Survey of India (SoI) toposheet (year-2001) of 1:50,000 scale using visual and digital image interpretation techniques through GIS software's. The final results highlight the application of geoinformatics technique in assessment of lithological units and geomorphological landforms on Precambrian rocks of KSZ, Chamarajanagar district, Karnataka, which is a suitable model for application to similar geological terrain.

Keywords: Geoinformatics, Lithology, Geomorphology, Precambrian rocks, KSZ

1. Introduction

The present study is undertaken to investigate lithologic contacts and geomorphological landforms of Kollegal Shear Zone (KSZ) using Survey of India (SoI) toposheet, satellite image with limited ground truth checking using GIS software. The study area represents a part of Biligiri-Rangan hills which belong to an oldest Precambrian hard rock terrain in Southern Karnataka. In Dharwar Craton, KSZ demarks the boundary between low-land amphibolite mixed gneisses and high-land Biligiri-Rangan Granulites (BRG) which trends N10°E to S10°W, where both retrograde and prograde metamorphic alterations are noticed (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1996, 1998 & 1999; Basavarajappa et al., 2004; Dinakar S., 2005; Meenakshi, 2003; Satish, 2002; Srikantappa et al., 1997 & 1999). The charnockitic-enderbitic granulites show ductile to ductile-brittle shear deformation between amphibolite facies and banded charnockites extending about 60-65km in length and 20-25km in width (Basavarajappa and Srikantappa, 1999). The eastern portion of the study area forms a hilly terrain with lofty mountains (Biligiri-Rangan hill ranges) raising about 1677m above MSL, run approximately towards N-S direction with thick vegetation. The western part forms a plain country with an average elevation of 686.25m with minor undulations. Honattikal, Chikkangiri betta and Honnamatti betta are some of the important tracts. The study area mainly consists of dominant rock types such as gneiss and charnockite. In addition, the terrain consists of amphibolite, banded magnetite quartzite, pyroxene granulite, pink migmatite, ultra mafic, hornblende schist and basic dykes. Geomorphology includes the study of drainage pattern, topographical aspects (altitude and slope), geomorphic landforms, etc (Miller, 1953; Sparks, 1983). The north western region is drained by major River Cauvery; while Kabini flow from west to east in southern parts and both the river conflicts at Tirumalkudalu Narsipura. Suvarnavathi and its tributary, Hebba halla flows from south to north in the central part of the study area, in turn drain into river Cauvery (Azadeh et al., 2011). The land adjoining the banks of meandering course of the river forms the most fertile and rich tracts, which is cultivated intensively for paddy and coconut. Geoinformatics application is an advent hi-tech tool that carried out in the study area for the first time for extraction, integration of information and its utilization for sustainable development (Basavarajappa et al., 2007) especially in cases where resources lie hidden below the earth's surface at certain depths. The paleo-channels of the study are also mapped using satellite data which gives additional information regarding water bearing zones like hidden aquifers, old river courses, fractures and valley fills (Basavarajappa et al., 2007 and 2013; Dinakar S., 2005; Satish et al., 2007).

2. Study area

The study area lies in between 11°45' to 12°15'N latitude and 76°45' to 77°15'E longitude with total areal extent of 3,011 km^2 (Fig. 1) which includes parts of 9 taluks of Karnataka state namely Yelandur, Kollegal, Chamarajanagar, Malavalli, Mysore, Gundlupet, T. Narsipura, Nanjungud and small patches of Tamil Nadu region (Sathyamangalam) in the southern and southeastern parts. Cauvery and Kabini are the two major rivers flowing in the study area in which Kabini is one of the tributary of River Cauvery. The average annual rainfall is 786.8mm (2004) with a major contribution South-West monsoon (44.45%)

with pleasant weather. The annual minimum rainfall is recorded as 558mm (Kavalande rain-gauge station) while the maximum is 1455mm (2010) (Biligiri-Rangan temple rain-gauge station). There is a continuous rise in temperature attaining a maximum in the month of April and minimum during December. Wind speed is moderate during South-West monsoon and relative humidity is high (Dinakar, 2005).

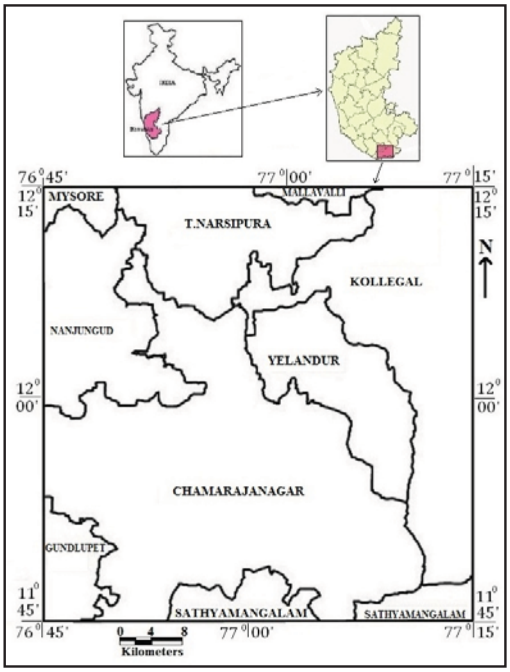

Figure 1: Location map of the study area

3. Methods and materials

3.1 Methods

Geoinformatics techniques are the advent hi-tech tool in analyzing, mapping and integrating the information database to generate thematic maps for development and management of natural resources (NRSA, 1995; Tiwari and Rai, 1996). Remote sensing has unique capability of extracting information of various landforms and lithology through image interpretation techniques (Dinakar et al., 2008). Lithological formations and geomorphological landforms are derived by visual image interpretation on IRS-1D PAN+LISS-III False Color Composite (FCC) based on the image interpretation elements such as association, pattern, shadow, shape, size, tone, texture etc., and verified during the field visits. Drainage and slope maps are digitized using SoI toposheet of 1:50,000 scale.

3.2 Materials used

a) Topomaps: 57D/16, 57H/4, 58A/13 and 58E/1.
Source: (SoI, Dehradun).

b) Thematic maps: Lithology, Geomorphology, Weathered, Drainage, Lineament, Soil and Slope.
Source: (National Bureau of Soil Survey), (Land Use Planning (NBSS & LUP) Bangalore, quadrangle maps of 1:250,000 (GSI, Calcutta).

c) Satellite data: IRS-1D LISS-III of 23.5m resolution (March and Nov-2001) and PAN+LISS-III of 5.8m, Date of pass 10-March-2003 (Fig. 2).
Source: (National Remote Sensing Agency [NRSA]), Hyderabad.

d) GIS software: Mapinfo v7.5, Arc Info v3.2, ERDAS Imagine v9.2 and Arc GIS v9.2.

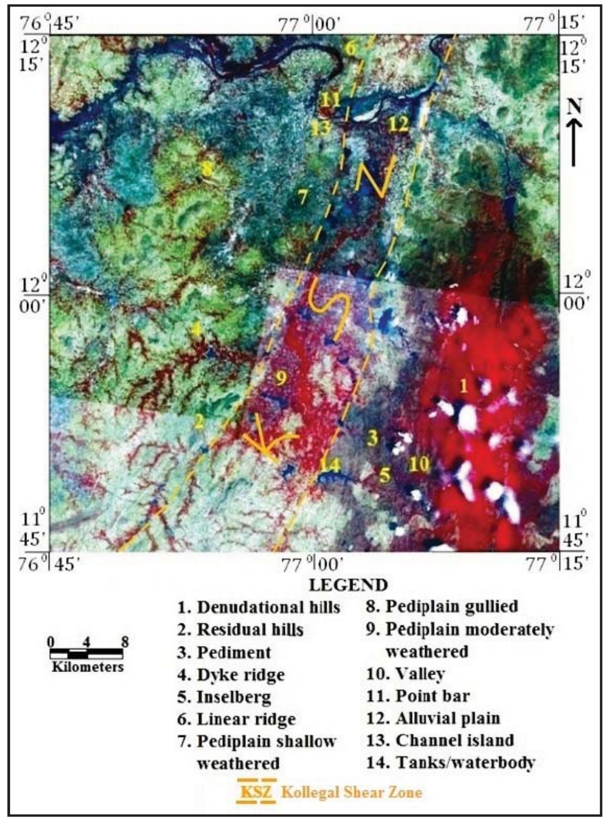

Figure 2: Satellite data of the study area

4. Weathered layered

Weathering is a natural process of disintegration and decomposition of rock. The intensity of the weathering depends on topography, climate, structure and tectonic setup of the area (Fig. 3). The thickness of the weathered zones varies from place to place due to variation in lithology, climate, intensity of weathering agent, slope etc. The amount of water holding capacity will be higher as the thickness of the weathered layered increases. Weathered zones mostly form shallow aquifers in the area and have been observed generally along low-lying areas, alluvial plains and natural tanks. To generate weathered layer map of the study area, 60 locations of bore well casing depth information has been collected. The casing pipe is inserted into the bore well up to where the hard rock or non-collapsible rock formations encounters providing the thickness of weathered layered indirectly. The obtained casing lengths are plotted on a base map and contoured to digitize the map representing spatial variation of weathered layered. The thickness of the weathered zone varies from 1 to 28m. The maximum thickness of the weathered zone is observed in central part that runs along KSZ and all along the river courses. While the minimum weathered thickness are observed in the southeastern part. Gneiss and migmatite rocks are deeply weathered as compared to the charnockite which occurs as hill ranges. Ranks have been assigned based on the thickness of weathering layers and are as follows: 1 to 10m denotes Rank-1, 10-16m denote Rank-2, 16-22m denote Rank-3 and 22-28m denote Rank-4 with a weightage of 25 (Dinakar S., 2005).

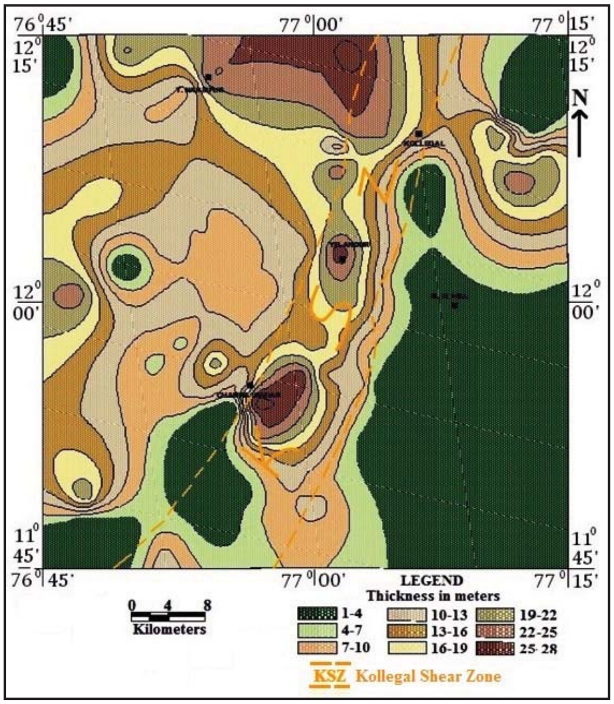

Figure 3: Weathered layered map of the study area

5. Geology

Geologically, the region belongs to an ancient Archaean terrain. It contains the main unit of Biligiri-Rangan hill ranges as both high land (charnockites) & low land (gneissic) rocks with metasediments (Basavarajappa, 1992). In between these two units, a charnockite-gneiss mixed zone (KSZ) exists. They possess a well-defined joint system and are dissected by a number of intrusions. Both the formations are intruded by basic dykes. Amphibolites occur as small and narrow lenticular patches in gneissic rocks. The Biligiri-Rangan hill ranges is considered as the reactivated margins of the Dharwar Craton, as it is made up of 3400 Ma old protoliths, and shows imprints of granulite metamorphism at 2500 Ma (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1999; Janardhan et al., 1994; Peucat et al., 1993; Srikantappa et al., 1992 & 1999; Srikantappa and Basavarajappa, 1997). Geochemistry of the study area has been carried out by earlier workers (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1998, 1999 & 2014a). The Biligiri-Rangan hill is bounded at its southern extremity, by the linear 20km wide Moyar-Bhavani Shear Zone which separates the Nilgiri granulite block from the Biligiri-Rangan hill granulite terrain (Prakash Narsimha et al., 2004; Srikantappa et al., 2003). At about 77°10' longitude, there is a mountain barrier forming Biligiri-Rangan and Male Mahadeswara hill ranges. These ranges rise abruptly from a flat ground to a height of 5000 to 6000ft (Basavarajappa et al., 2013; Wadia, 1999). There is an abrupt truncation of the old and the new plateau surfaces at the point where the high mountain ranges of the Biligiri-Rangan hill appears. The precipitous drop by nearly 600ft and the slicken-sided surface of the Biligiri-Rangan scarp also probably represents one such fault. Traces of boundary fault, along with such uplift took place in the case of Biligiri-Rangan charnockite massif, that seen to be remarkably straight course of the river Cauvery towards east of Male Mahadeswara hill ranges. Due to geo-environmental conditions, the geomorphic units also vary from place to place (Wadia, 1999).

6. Lithology

The lithology map is prepared using published Geological map of Karnataka 1:250,000 scale (GSI, 1981) and updated on satellite imagery IRS-1D using MapInfo v7.5 (Fig. 4). The study area mainly consists of dominant rock types like amphibolite gneiss and charnockite. In addition, the terrain consists of gneiss, charnockite, pyroxene granulite, amphibolites, hornblende schist, meta ultramafite, banded magnetite quartzite, basic dyke and migmatite (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1998; Basavarajappa et al., 2013 & 2014b; Dinakar S., 2005; Meenakshi, 2003; Satish, 2002; Srikantappa et al., 1992 & 1999; Srikantappa and Basavarajappa, 1997). Different minerals and rocks have got varying spectral responses under different spectral reflectance under visible, near, mid and thermal infrared of electromagnetic spectrum. The color, crystal system, hardness, specific gravity, cleavage, fracture and birefringence etc., greatly alter the spectral reflectance (Ramasamy et al., 1993). In the study area, percentage of quartz, ferro magnesium minerals, feldspar, silica, aluminum, iron oxide alters the spectral responses of the mineral and its aggregates (Dinakar, 2005). The contacts of litho units can be accurately marked and extended using the tonal characteristics in satellite imagery with limited ground truth checks.

6.1 Gneiss

Gneiss is the dominant, plain country rock forming N-W and S-E portion of the study area. General trend of gneissic foliation is N-S to N15^{0}E with a steep dip of 65^0 to 80^0 towards East. They are medium to coarse grained and exhibit banding with leucocratic rich layers alternating with melanocratic biotite rich layers. They are highly weathered and traversed by intricate network of drainage patterns. The gneiss is well exposed in the village limits of Mangala, Ummatur, Jannur, Mallianapura, Bisalvadi, Bokkapura etc. Gneiss shows light yellowish green color on FCC mainly due to presence of leucocratic minerals such as quartz, plagioclase and potash feldspar (Fig. 4).

6.2 Charnockite

The study area represents composition variation in Charnockite from enderbites, charno-enderbites to granulites (Basavarajappa, 1992; Basavarajappa and Srikantappa, 1999; Srikantappa et al., 1992). They are medium to coarse grained, light gray to greasy gray colored rocks. Foliation is generally visible due to well-banded nature, trending N-S to N20°E with dip of 65°W to vertical. The general greasy appearance of charno-enderbites shows alteration due to weathering. The entire charnockite terrain is surrounded by youthfully rugged high hills which are structurally controlled mountain ranges with steep slopes, scarp faces, narrow gorges and long parallel ridges. Small enclaves of charnockite are noticed within the gneiss and migmatites rock near the villages' viz., Ramapura, Talavadi, Ikkadahalli, Aralipura and few in southeastern part. Charnockites are well exposed on the ridges of Biligiri-Rangan hill ranges, and are observed as dark gray patches on FCC mainly due to presence of dark color minerals like pyroxene and hornblende (Fig. 4). Charnockite are normally massive, compact and are devoid of significant joint at depths. They are less prone to weathering.

6.3 Pyroxene granulite

It occurs as linear concordant band ranging in width up to 200m within charnockite. Pyroxene granulite bands occur extensively in the area Chikkaindavadi, Doddagumpy betta, Honnametti betta and Bedguli. Mineral compositions of pyroxene granulite consist of plagioclase, clinopyroxene, orthopyroxene, garnet with minor amount of quartz and hornblende. On FCC, it occurs as very small bands and difficult to identify (Fig. 4).

6.4 Amphibolite

It occurs within the charnockite and gneissic terrain parallel to regional foliation, the amphibolites occur as enclaves, in different sizes and exhibit sharp to diffused contacts with gneisses. It is typically dark-colored, heavy and foliated. The small flakes of black and white in the rock often show salt-and-pepper appearance. They are coarse-grained with gabbroic texture consisting of tabular plagioclase with interstitial clinopyroxene and greenish brown hornblende. Amphibolites are found in Kathanattana gudda, Channamallipur, Kokkanahalli, Puttanapur, and Kumbesvaran kovil. The amphibolites are composed of hornblende, plagioclase, clinopyroxene, sphene, apatite and magnetite. Amphibolites are easily identified by its dark greenish color and coarse texture on FCC (Fig. 4).

6.5 Hornblende schist

It occurs as small and narrow lenticular patches in gneisses. Mineralogically, it consists of hornblende grains aligned parallel to schistosity and rare alteration to chlorite is observed. The area is almost pediplain to undulating topography and few small hills are noticed. It is well exposed in Mudukutharai temple, Bilijagali mole, Bellegudda, Bisalavadi, Badanaguppe, Galipura. It appears as massive greenish streak on FCC (Fig. 4).

6.6 Meta ultramafite

They enclaves are seen as pods and lenses with the longer axis of the lenses aligned parallel to gneissosity of enclosing charnockite. They are medium to coarse grained melanocratic rocks. The enclave shows gradational in composition from olivine rich greenish cores to brownish orthopyroxene rim and grade on finally to biotite rich selvedges. Abundant intrusions of layered ultramafic rocks are encountered in Terakanambi, Kattalavadi, Linganapura, Arakalavadi, Honnahalli, Karivaradaraya betta appearing as massive greenish streaks on FCC. Ultramafic enclaves are more significantly recrystallised under granulite facies condition and are shown by fresh olivine, orthopyroxene and clinopyroxene assemblages.

6.7 Banded Magnetite Quartzites (BMQ)

Exposures of Banded Magnetite Quartzites (BMQ) are noticed in charnockite gneiss as a mixed zone along the foliation of the country rocks. They range from 1 to 10m in size. These are generally parallel to regional trend of N5°-15°E with vertical dip. They are folded with alternate layers of magnetite rich bands with layers of pyroxene and garnet. BMQ are found in Cheiuvanahalli, Dhanagere, Devarabetta, Tumbe betta and Honneparai betta. The mineral assemblage of BMQ includes quartz, magnetite, clinopyroxene, garnet and orthopyroxene. BMQ are difficult to identify in FCC due to thick soil and vegetation cover.

6.8 Dolerite dykes

Numerous late dolerite dykes transect gneiss and Biligiri-Rangan massif. These dykes cross cuts the river and all the other lithological units including the migmatitic gneiss exhibit sharp contact with them. Dolerite contains plagioclase and clinopyroxene which can be identified in hand specimen. Clinopyroxene (augite) shows two sets of cleavages almost parallel. They are found in Terakanambi, Arakalvadi, Manchgundipura and Kumachahalli. These dykes are observed on the satellite data in the form of bands, sometimes discontinued with black signature.

6.9 Migmatites

Migmatites are formed in extreme temperature-pressure conditions, where partial melting occurs in pre-existing rocks. Migmatites are composed of a neosome, new material crystallized from incipient melting and a paleosome; old material that resisted melting. In the study area, the migmatitic peninsular gneisses are of tonalite-trondhjemite-granodiorite in composition. The migmatites are abundantly exposed in Biligiri-Rangan charnockite massif, east of Kollegal, Mathuvanahalli, Palya and Sattegala.

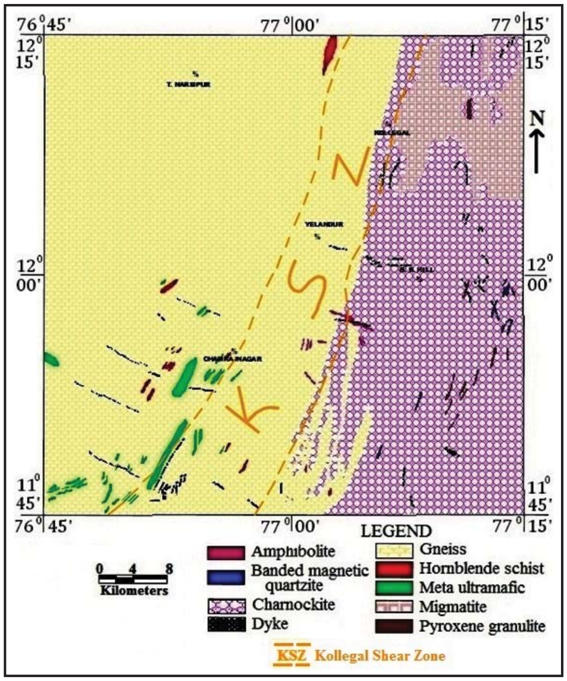

Figure 4: Lithology map of the study area

7. Geomorphology

Geomorphology is defined as scientific study of landforms. The geomorphology map is digitized using satellite image IRS-1D LISS-III data (Table 1) using ArcGIS, v9.2 (Fig. 2 & 5). The geomorphology includes the study of topography, drainage pattern and geomorphic units (Basavarajappa and Srikantappa, 1998; Basavarajappa et al., 2013; Dinakar S., 2005; Miller, 1953; Satish et al., 2007; Sparks, 1983)

7.1 Denudational hills

They are formed due to differential erosion and weathering; so that a more resistant formation or intrusions stand as mountains/hills. The denudational hills are marked by sharp to blunt crest lines with rugged tops indicating that the surface run-off at the upper reaches of the hills has caused rill erosion. They are noticed in eastern part of the study area. The lithological constitutions of these geomorphic units are charnockite. These geomorphic units occur as continuous range of varying heights and generally act as run off zones and are highly disturbed due to the presence of joints, fissures and shear zones. These landforms shows bright red to dark red tone with coarse to medium texture depending upon density of crown on the image (Fig.2 & 5; Table 1). Northeastern parts are covered by scanty vegetation and show greenish to dark gray tone (Basavarajappa and Srikantappa, 1998; Dinakar, 2005; Pushpavathi, 2010; Satish et al., 2007).

7.2 Residual hills

These are isolated low relief and irregular outlines standing out predominantly and appear as isolated hills or continuous chains of hillocks due to differential erosion. Thus, more resistant formation or rocks stand as residue like hills usually marked with structures such as joints, fractures, etc. with varying lithology. It appears as brownish tone due to exposed rock outcrops and varied reddish tone in some area due to partial growth of vegetation on standard FCC image (Fig.2 & 5; Table 1). Residual hills composed of meta ultramafite and gneiss rocks with varying elevations are concentrated towards the southwestern part of the study area.

7.3 Inselberg

An isolated hill of massive type abruptly rises above the surrounding plains. In the study area, inselbergs occur in the form as residual isolated barren or rocky smooth and rounded small hill (mostly conical) standing above ground level surrounded by pediplains. These geomorphic units are well exposed near the village Mangala, Kadavinkattehundi, Jodigere and Vadagere. It exhibits grey tone on standard FCC image (Fig. 2 & 5; Table 1).

7.4 Pediment

It is a gently sloping area with erosional bedrocks situated in between hills and plains consisting of a veneer of detritus and broad undulating rock floor. The river and streams that have cut gorges give rise to terrace across the undulating and low plateau like drift deposits, thereby forming a typical pediment landscape (Mukhpadhyay, 1994). Groundwater condition in pediments is expected to depend upon the type of underlying folded structures, fracture system and degree of weathering (Girish and Seralathan, 2004). The large area covered under the unit pediment is observed in contact between two litho units; gneisses and charnockite occurred in KSZ. They exhibit dotted outcrops and light brown tone over charnockite & gneissic rocks on standard FCC (Fig. 2 & 5; Table 1).

7.5 Linear ridge

It generally occurs as linear to curvilinear, narrow, low lying relief and are generally barren. This unit occupies northern part of study area near village Mudukuthorai. The N-S trending strike ridges are developed mainly on hornblende biotite schist. These geomorphic units are also well exposed near the villages of Hulaganamuradi, Kilgere and Bagali. It appears as grey to greenish tone on standard FCC image (Fig. 2 & 5; Table 1).

7.6 Pediplains

Gently undulating plain of large areal extent often dotted with inselbergs formed by the coalescence of several pediments are termed as pediplains. These occupy semi-consolidated sediments from good aquifers depending on their composition. In the study area, based on the thickness of weathered column, pediplains are divided into two sub-zones viz., moderately weathered pediplain and shallow weathered pediplain as described below.

7.6.1 Pediplains moderately weathered: The unit occupies the topographically low-lying area with weathered zone thickness ranging from 10 to 20m.

Pediplains moderately weathered are observed at central and northern part of the study area. River Suvarnavathi flows in NNE direction and empties itself into the river Cauvery at Hampapura near Kollegal. Adjacent to this river, large areas of pediplains moderately weathered are noticed. They appear with bluish to grey tone on standard FCC image (Fig. 2 & 5; Table 1).

7.6.2 Pediplains shallow weathered: Flat and smooth surfaced with weathered zone thickness ranging from 0 to 10m. Pediplains shallow weathered occur as vast tracts of fallow upland areas with sparse vegetation. Rainfed crops are being raised at some places. This geomorphic unit found in gneissic rock shows light yellow to greenish color on standard FCC image (Fig. 2 & 5; Table 1).

7.7 Pediplains gullied

They are formed due to high erosion on loose soils. Irregular dissected portions with a number of gullies are observed near the villages of Bagali, Hosur, Vatalu, Hadya and Kalkunda. They are found adjacent to pediment and linear ridge on gneissic rock. It appears in light yellowish to whitish in color on standard FCC (Fig. 2 & 5; Table 1). According to (Kirkby and Carson, 1972) gullies or rills are geomorphic feature typically develops on exposed slopes where the gradients vary from 3°- 35°.

7.8 Alluvial plain

Nearly level plain formed by the deposition of alluvium by major rivers are known as Alluvium plains. These alluvial plain area are older meander scars, point bar deposit, flat terrain, grayish white to grey loamy soil-fine sand, silt and clay with high moisture content mainly due to double crop area. These geomorphic units are found adjacent to major rivers Cauvery and Kabini. They form good to excellent shallow aquifer due to nature of alluvial, its thickness and recharge condition. They exhibit bluish to dark grey tone on imagery (Fig. 2 & 5; Table 1).

7.9 Valleys

They are low lying depression and negative landforms of varying size and shape occurring within the hills associated with stream/nala course. These are unconsolidated alluvial and colluvial materials partly or wholly filled in valleys by streams and rivers. Valleys are noticed in southwestern portion of the study area and are characterized by presence of vegetation growth along the side of valley. It exhibits reddish tone due to the presence of vegetation on standard FCC image (Fig. 2 & 5; Table 1).

7.10 Channel island

An island formed in the braided river course is termed as Channel Island. In the study area, it is found close to the present course of River Cauvery in the form of channel bars and sand bars. It shows bluish color on standard FCC (Fig. 2 & 5; Table 1).

7.11 Point bar

Sand bar formed at the convex side of meandering river by lateral accretion of sediments are termed as point bar. These geomorphic units are found near Talakadu, where meanders of River Cauvery are noticed. On standard FCC image, it appears as white tone and pale red where scanty vegetations are observed (Fig. 2 & 5; Table 1).

8. Drainage

Drainage patterns are the reflections of surface and subsurface characters. Fine drainage density reflects higher surface runoff. The drainage map is prepared using SoI toposheet (Basavarajappa et al., 2013). The drainage patterns of the study area are derived by IRS-1D PAN+LISS-III using ArcGIS v9.2 (Fig. 6 & 7). Numerous factors govern the drainages such as initial slope, lithology & structures and meteorological parameters. Precipitation is distinctly assertive in the generation of drainage pattern. The drainage system of the study area belongs to the Cauvery river basin and its tributaries Suvarnavathi & Chikkahole. The study area shows varied drainage patterns viz., trellis, rectangular, sub-parallel, radial, dendritic, sub-dendritic, deranged, anastomatic and dichotomic patterns (Basavarajappa et al., 2013).

9. Lineament

Lineaments and fractures play a vital role in controlling the movement and storage of groundwater in hard rock terrain (Ramasamy et al., 2005). They provide pathways for groundwater movement and are hydrogeologically very important (Basavarajappa et al., 2013; Sankar et al., 1996). The lineament map is prepared by IRS-1D PAN+LISS-III through MapInfo v7.5 (Fig. 8 & 9). Length and direction of the lineament has been calculated using ArcView v3.2. Most of the lineaments are trending towards N-N10°E direction. These lineaments are straight, structurally controlled and represent foliation trend. Most of the wells, ponds, tanks which falls under these lineaments provides good yield. The fracture system represent deep seated faults, master fracture and joint sets through which magmatic and metalliferous fluids are brought to the surface, groundwater movement take place along them, act as zones of erosion, geothermal springs and also act as neotectonic windows through which earthquakes and seismicity take place. In hard rock terrain, occurrence and movement of groundwater depends on the secondary porosity such as lithological contact, unconformities, folds, faults, bedding plains, fracture, joints, shear zones, etc. Lineaments are important in rocks where secondary permeability and porosity dominate and inter-granular characteristics combine in secondary opening influencing weathering, soil, surface and groundwater movement. Areas with high lineament density are good for groundwater prospect zones (Haridas et al., 1998).

Journal of Geomatics Vol 9 No. 1 April 2015

Table 1: Image Characteristics of various geomorphological landforms of the study area (as seen in FCC)

Geomorphological landforms	Tone/color	Texture	Size	Shape
Denudational Hill	Brownish color where outcrop exposed Reddish where vegetation are present	Coarse	Large	Isolated
Residual Hill	Brownish to Reddish	Coarse	Large to medium	Isolated
Inselberg	Grey to Greenish	Coarse	Small	Isolated
Pediment	Light brown	Coarse to medium	Medium to Small	Irregular
Linear Ridge	Yellowish	Linear	Medium	Isolated
Pediplain	Yellowish brown	Coarse to Medium	Medium to Small	Irregular
Moderately Weathered Plain	Light red to dark red	Fine	Irregular & large	Irregular
Shallow Weathered Pediplain	Light yellow to greenish	Medium	Wide spread	Irregular
Pediplain Gullied	Yellowish to whitish	Coarse to medium	Medium spread	Irregular
Alluvial Plain	Bluish to dark grey	Fine	Irregular & large	Irregular
Valley	Reddish	Fine	Varying related to channel width	Drainage like pattern
Structural Hills	Bright white to pale red	Coarse to medium	Irregular & large	Irregular
Channel Island	Bluish color	Fine	Small	Convex

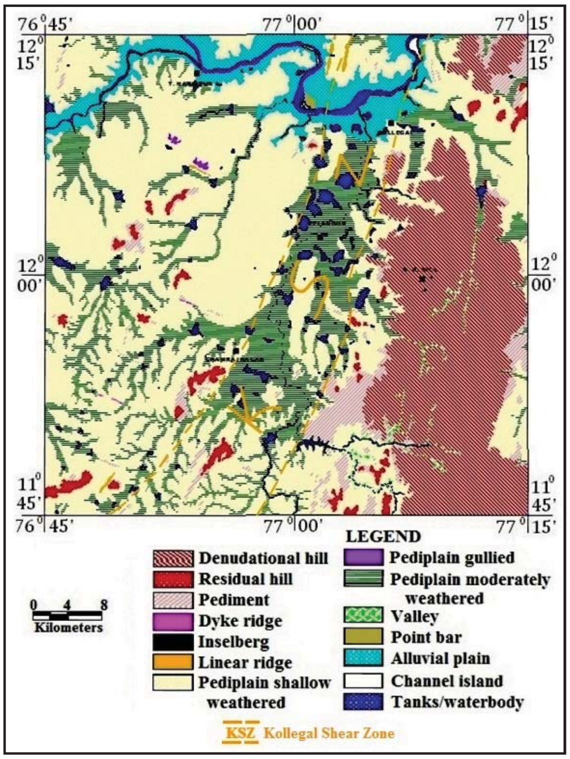

Figure 5: Geomorphological landforms of the study area (as seen in FCC)

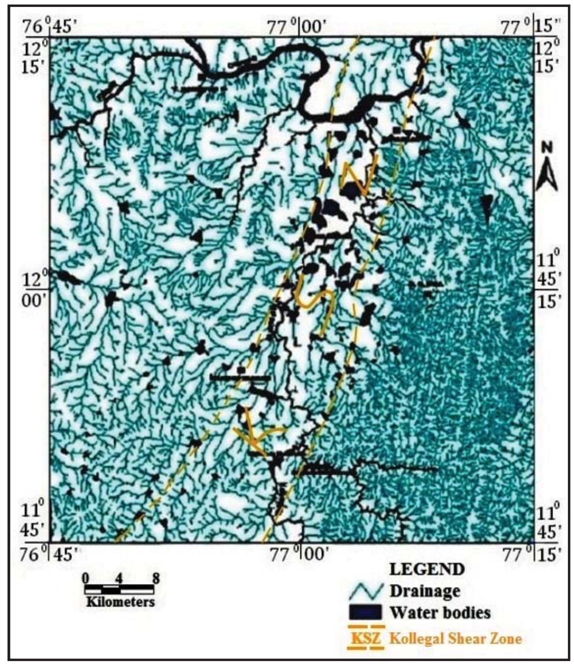

Figure 6: Drainage map of the study area

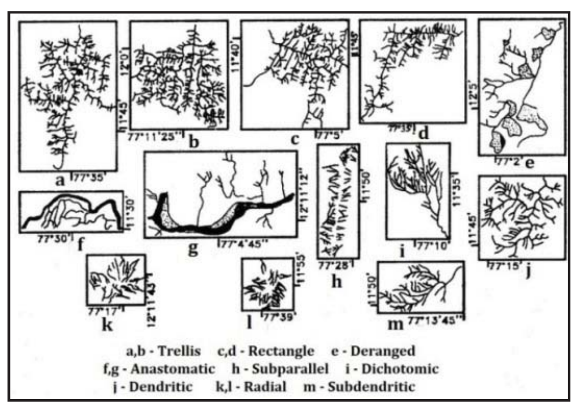

Figure 7: Drainage patterns of the study area

Figure 8: Lineament map of the study area

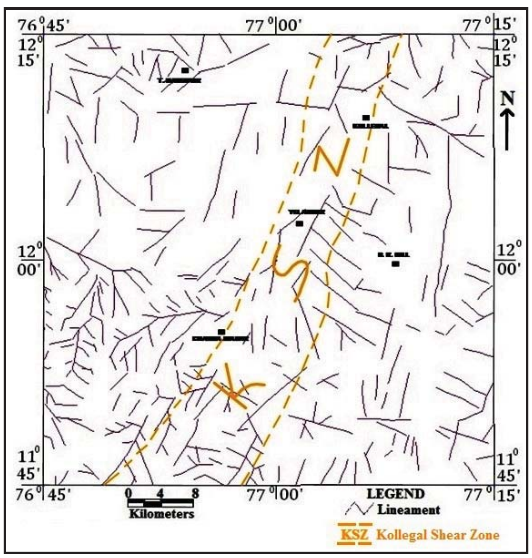

Figure 9: Lineament overlaid on satellite data (Band: 1, 2 and 4)

10. Soil

Soils are essential units in controlling the infiltration of rainwater and surface flow patterns (Basavarajappa et al., 2014b). Soil moisture consists of organic and inorganic materials, water and air (CGWB, 2008). The soil map of the study area is prepared by satellite imagery IRS-1D PAN+LISS-III using MapInfo v7.5 (Basavarajappa et al, 2012) (Fig. 10). Different soil types identified in the study area are as follows:

10.1 Clayey soils

It occurs in pediplains, deposited along stream and varies in their thickness. They are very deep to deep, well drained, dark reddish brown to dark red in color, occurs on gently sloping land with moderately eroded and occurs nearly gneissic terrain. Due to thickness and fineness, the water holding capacity is generally high with moderate to poor runoff and low permeability.

10.2 Clayey mixed soils

They are shallow, well drained, dark brown with mixed mineralogy. They occur on undulating to rolling land of contact between charnockite and gneissic rocks with moderately eroded.

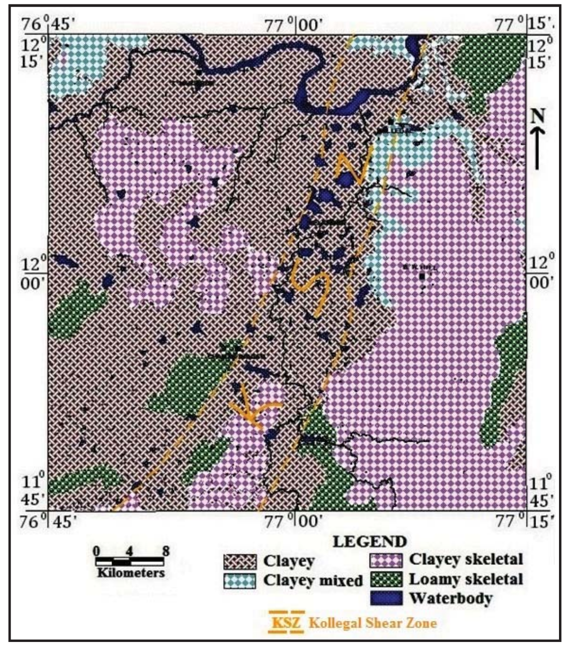

Figure 10: Soil map of the study area

10.3 Clayey skeletal soils

These are observed in upper slopes of pediments and hilly regions. They are shallow to excessively drained, reddish brown to yellowish brown gravelly sandy loam to gravelly clay loam. These occur along hills and ridges of Biligiri-Rangan hill ranges and act as rapid runoff and high permeability.

10.4 Loamy skeletal soils

They are shallow, well drained, dark brown consist of more than 35% gravel with moderately eroded and occurs on undulating to rolling land (Dinakar S., 2005).

11. Slope map

Slope map is prepared by SoI topographical map on 1:50,000 scale by adopting template method (AIS & LUS, 1990) and digitized through Erdas Imagine v9.2 (Fig. 11; Table 2). Slope is the loss or gain in altitude per unit horizontal distance in a direction. It may be dependent on lithology, climate, meteorological parameter, runoff, vegetation, geological structure and the process of denudation & that can estimate the run-off and erosion. The maximum development of slope is found in the hilly terrains. Several methods have been suggested to calculate the slope value (Unwin, 1981; Wentworth, 1930). Slope map of an area provides information regarding the distribution of various slope classes and helps in understanding the runoff characteristics of the watershed (Basavanna, 1996). It is helpful in prioritizing areas for developmental measures and identification of suitable areas for agriculture (Sreedhara et al., 1996).

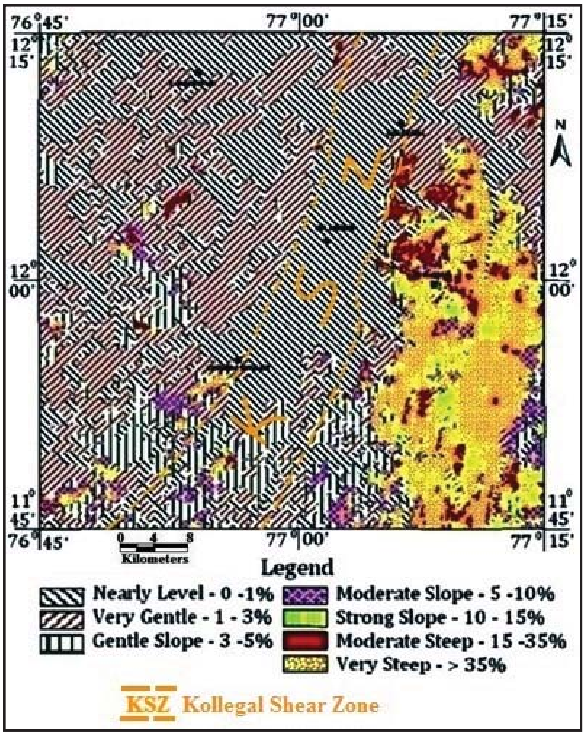

Figure 11: Slope map of the study area

12. Slope aspects

The slope aspect information has been derived from SoI toposheet on 1:50,000 scale (20m contour interval) using (AIS & LUS, 1990) guidelines on slope categories. Higher degree of slope results in rapid runoff and increased erosion rate occur with feeble recharge potential (Magesh et al., 2011). Major part of the study area is dominated by nearly level slope (35%) varying from 0° to 1°, contributing the central, northwest and southwestern part as low laying area of gneissic terrain. These regions mainly falls under pediplain landforms, adjacent to the river Cauvery and its tributaries Kabini and Suvarnavathi. The second most significant slope category is the very gentle slope (30.6%) varying from 1° to 3°noticed at northwest and southwestern part of gneissic terrain and some portions in northeastern parts of amphibolites rock. The third most significant slope category is the very steep slope (11.89%) varying >35° contributing towards southeast part of charnockite area of the Biligiri-Rangan hills. They represent terrains having escarpments, parallel ridges, valleys, cliffs initiated in the slope. The fourth most significant category is the gentle sloping areas (9.49%) varies from 3^0 to 5^0 occupying southwest parts of the study area. The pockets of varying slope within the low lying gneissic terrain is represented by residual hills, ridges, mounds, spurs and peaks falls under this class. Moderately steep to steep sloping, strongly sloping, moderately sloping areas contribute only small portions of 2.74%, 5.86% and 4.38% respectively varying from 5^0 to 35^0. These are noticed towards southeastern part of the study area near Biligiri-Rangan hill ranges, and also occur in southwest parts near Tiruknambi and Mudukuthorai betta in the north.

Table 2: Slope categories of the study area

Sl no	Slope Category	Lower and Upper Limit of Slope Percentage	Lower and Upper Limit of Contour Spacing (cm)	Area (km^2)	Percentage (%)
1	Nearly level	0 – 1	>4	1054.1	35.00
2	Very gently sloping	1 – 3	1.33 – 4	922.2	30.62
3	Gently sloping	3 – 5	0.80 – 1.33	285.9	9.49
4	Moderately sloping	5 – 10	0.40 – 0.80	131.9	4.38
5	Strongly sloping	10 – 15	0.26 – 0.40	176.4	5.86
6	Moderately steep to steep sloping	15 – 35	0.10 – 0.26	82.8	2.75
7	Very steep sloping	>35	0.11 and above	358.1	11.89

13. Results and discussion

The peninsular gneissic terrain is a tableland of flat to undulating topography. Slope in nearly level to gently sloping. Pediplain and pediment are noticed to be characterized by absence of any major hills and mounts. Alluvial plain, few small ridges and hills are also observed. The drainage system of the study area belongs to River Cauvery and its tributaries Suvarnavathi. The drainage patterns are rectangular, trellis, dendritic to subdendritic, sub-parallel, radial patterns are noticed at hills, mountainous areas and anastomatic, dichotomic and deranged patterns are noticed at the low land areas. Generally pediplain gullied are affected by intense soil erosion due to streams and local drainage. Paleo-channel dominates this plain to make it very fertile.

14. Conclusions

Remote Sensing with its multi-spectral, temporal, spatial and synoptic view provide accurate spatial and temporal information of the study area carried out for the first time and digitizing the datasets through GIS software using GPS during field visits. Geologically, banded enderbitic charnockite, amphibolite-biotite and migmatitic gneisses are dominant rock types exposed in high land areas and low land areas of the study area. The terrain is geomorphologically characterized by youthful rugged high hills and structurally controlled mountain ranges with steep slopes, scarp faces, narrow gorges and long parallel ridges. The hill slopes are having steep valleys and triangular facets. Pediplains are noticed near the river courses. Geomorphology is the imprint of the geology and structural settings of a region. The stream courses are structurally controlled and join the main streams approximately at right angles. Most of the stream courses are narrow and are controlled by lineaments. However, the topography changes drastically where the bedrock lithology is peninsular gneiss of the shear zone. The high categories of respective variables are seen to be influenced by the scarps and adjacent ridges, while the pediplains and plateaus are characteristic of the low and medium categories. The river system, drainage network, paleo-channels, structural features, fracturing, shearing, weathering of high grade Precambrian rocks are highly influenced on the topography, slope, thickness of the lithounits, distribution of water body systems of the NS KSZ.

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