CHAPTER-III

GEOLOGICAL CONFIGURATION

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3.1 Geology of Karnataka

The State of Karnataka is geographically located from 11° 5' to 18° 5' N latitudes and 74° 0' to 78° 5' E longitude. It is bounded by Maharashtra and Goa States in the north and northwest; by the Arabian Sea in the west; Kerala and Tamil Nadu in the south and the Andhra Pradesh in the east (Fig: 3.1). Karnataka extends to about 750 km from north to south and about 400 km from east to west. The highest point in Karnataka is the Mullayananagiri hill in Chikkamagalore district which has an altitude of 1,929 meters (6,329 ft) above MSL.

The peninsular shield of India, of which the Karnataka plateau constitute an important part, is one of the main Precambrian shield areas of the world. Geologically, Karnataka state is bounded on the west by the Arabian sea with stretch of coastal sediments and on the east by the high grade granulitic terrain of Tamilnadu and Andrapradesh. In the north, it is truncated by the Godavari graben and covered by the sediments of late Proterozoic and Deccan traps of cretaceous- Tertiary age. In south, the boundary is less well defined and is represented by Tamilnadu- Kerala granulitic terrain.

There are four main types of geological formations in Karnataka

- The Archean complex made up of Dharwad schists and granitic gneisses: These cover around 60% of the area of the state and consist of gneisses, granites and charnockites. Some of the economic and rocks minerals found in this region are dolomite, limestone, gabbro, quartzite, pyroxenite, manganese and iron ores and metabasalt.

- The Proterozoic non-fossiliferous sedimentary formations of the Kaladgi and Bhima series: The Kaladgi series has horizontal rocks that run for 160 km in the districts of Belgaum, Raichur, Dharwad and Bijapur districts. The Bhima series that is present on either side of the Bhima River consists of different rocks like
sandstone, limestone and shale and these are present in the Gulbarga and Bijapur districts.

- The Deccan trappean and intertrappean deposits: This is a part of the Deccan traps which were formed by the accumulation of basaltic lava. This is made up of greyish to black augite-basalt.

- The tertiary and recent laterites and alluvial deposits: Laterite capping is found over the Deccan Traps and were formed after the cessation of volcanic activity in the early tertiary period. These are found in many districts in the Deccan plateau and also in the coast (Radhakrishna and Vaidyanadhan, 1997).

Southern part of Indian shield mainly consists of Archaean and Proterozoic rocks which forms the Karnataka Craton / Dharwar Craton (Swaminath and Ramakrishnan, 1981), also called Karnataka-Andhra Pradesh Craton (Radhakrishna, Pichamuthu and Srinivasan, 1983). Dharwar Craton is principally composed of Peninsular gneisses and Supracrustal belts which are generally referred to as the schist belts / greenstone belts. In 1872 Bruce Foote coined the term “Dharwar System” to those schistose formation, which occupy nearly 1, 28,000 sq kms in the state which are well exposed around Dharwar. Based on the lithological, stratigraphical, metamorphic grade and tectonic observation of greenstone belts, the regional Dharwar Craton are categorized in to four units (Radhakrishna, 1994). They are Younger Dharwar green stones, Older-gold bearing Kolar type, Supracrustal units and Ancient Sargur type. Primarily four types of Schist belt exist within the Karnataka State; they are Bababudan schist belt, Shimoga schist belt, Chitradurga - Gadag schist belt and Sandur schist belt. According to the hydro-geological classification (NRSA), the lithological formation of South Indian Shield is reorganized into six types, such as 1) River alluvium, laterites and minor intrusives, 2) Deccan traps, 3) Puranas (Kaladgis and Bhimas), 4) Closepet granites and Ultrabasics, 5) Dharwars and 6) Peninsular gneisses.
Dharwar craton has been divided into the Eastern and Western tectonic blocks called as the Western and Eastern Dharwar cratons (WDC & EDC) with a Transition Zone straddling the Chitradurga Boundary Fault and the linear Closepet Granite. WDC is a stable block since the cratonization around 3000 Ma, after the Sargur orogeny. The stable block consists of Sargur Group (3300-3000 Ma) of ancient greenstone belts dominated by komatiite-tholeiite volcanics, BIF and minor shelf sediments that are intruded by layered basic complexes well exposed in Sargur, Hole Narasipura, Nuggihalli, Nagamangala and similar belts. These belts are completely engulfed by Peninsular Gneiss comprising tonalite-trondjemite-granodiorite (TTG) suite and trondhjemite-granodiorite plutons involved in a major thermal event at ~3000 Ma. Neither the true Sargur rocks nor the well-defined Peninsular Gneiss is exposed in the EDC, and that is why the WDC is sometimes described as Karnataka Nucleus.

The entire Dharwar craton (WDC and EDC together) is occupied by the younger succession of Dharwar Supergroup (2800-2600 Ma) exposed in the large schist belts Bababudan, Western Ghat, Shimoga and Chitradurga in WDC, and Ramagiri-Hungund, Kolar-Hutti, Velgallu-Gadwal greenstone belts of EDC (M. Ramakrishnan, 2008). Regional geology of the Karnataka state is shown in Fig: 3.1.
Regional Geology of Karnataka State

LEGEND
Geological Units
- Acid volcanics
- Acid volcanics with polymict conglomerate
- Alluvium
- Amphibolite
- Basal Polymict Conglomerate
- Basal conglomerate
- Basal polymict conglomerate with uranium and gold
- Basal volcanics
- Basaltic volcanics with sediments
- Charnockite
- Cherty limestone and shale
- Conglomerate, shale and cherty dolomite
- Cross bedded quartzite
- Dolomite
- Ringed flow no. 3 with intertrappean marl (Basalt)
- Gleno-phyric Flow No. 1 (Basalt)
- Granular ferrosilite
- Granodiorite and granite
- Greywacke, argillite, with ferruginous chert
- Nongraywacke, Argillite
- Holomorphic Shale
- Karwar Shale
- Katamadivel Shale, Limestone
- Laterite
- Limestone and dolomites
- Lower grey limestone
- Metagreywacke, gabbro and serpentinite
- Metabolite
- Metabasalt including thin sandstones
- Migmatic and granodiorite to tonalitic gneisses
- Orthoquartzite
- Phyllite quartzite
- Quartz-pelite, schist and greywacke
- Pink hornblende granite
- Pink porphyritic and pegmatite granite
- Polymict conglomerate
- Porphyritic Flow No. 2 (Basalt)
- Quartz-chlorite schist with orthoquartzite
- Quartzite and conglomerate
- Ramanapalli Shale, with thin sandstone and conglomerate
- River
- Shahabad Limestone
- Shale
- Shale and dolomites
- Shale and variegated limestone
- Triassic
- Ultramafic-Mafic complex
- Ultramafics
- Undifferentiated Flow (Basalt)
- Upper grey limestone
- Variegated limestone

Fig: 3.1 Regional geology of Karnataka State. (Adopted from Karnataka State Remote Sensing Application Centre, Bangalore).
3.2 Geological information of Shivani watershed

The Geology of the study area is spatially located between 13° 36' to 13° 55' N latitudes and 75° 53' to 76° 12' E longitudes, covering an aerial extent of 593.56 sq. km. (Fig 3.2). The Shivani watershed falls under Archaean and Proterozoic greenstones of Chitradurga schist belt (approximately 3000-2600 million years based on the radioactive elemental result).

Geology of an area plays a vital role in the distribution and occurrence of ground water. Krishnamurthy and Srinivas (1995) and others carried out various geological studies in different terrains and proved that IRS-1A and IRS-1B data can be effectively used for geological mapping. In the present study, geological mapping is updated upon using enhanced IRS-1D LISS-III satellite data. The image is first rectified by projecting it onto a plane by using UTM (WGS84) map projection method. A first order polynomial and Everest1830 spheroid are considered for the computation of transform matrix. The rectified image is then enhanced through linear stretching and principal component analysis using image processing software ERDAS 8.5 for better exposition of hydro-geological features. GIS is used for the mapping of features by activating a live-link facility between image processing software ERDAS and GIS package MapInfo Professional 8.5. The regional geologic units were updated based on the remotely sensed data, previous literature and field observation, geological map for the study area has been prepared (Fig: 4.2) using GIS.

Based on the literature survey and visual interpretation of satellite data coupled with geological field work, lithounits have been identified and described Banded Gneiss, Migmatites and granodioritic to tonalitic gneisses and Tonalite cover the major part followed by Conglomerate, Channagiri Ultramafic-Mafic complex, Granite(Sensu Lato), Limestone, Quartzite, Ultramafic enclaves and V-Ti Magnetite. The general trend of the formations is NNW to SSW (Dharwarian trend) and dipping NW and NE direction (From 15° to 80°), these formation form part of Chitradurga schist belt (Plate : V, Fig. b).
The Hanumalapur (15 km south of Channagiri) Complex one of the platinum bearing formation forms a part of study area. This complex has been investigated extensively for platinum mineralization (Alapieti T.T et.al 2008): This complex is a narrow sill-like body. Platinum ore is found to be concentrated in the form of narrow lenses running over 3.5 km strike length with a width of 300m and having a concentration of approximately 2.7 ppm of PGE. This complex has been metamorphosed to upper green schist through lower amphibolite facies and the corresponding deformation has completely destroyed the original textures as well as the primary mineralogy. The complex is bound on both sides by tonalite-trondhjemite gneiss and the contact between the two comprises a shear zone. It also displays a rough zoned structure composed of a central, 100–150m thick ultramafic zone, and outer gabbroic zones (Risto Kaukonen, 2008). Fig: 3.2 depict the geology of the watershed. The lithounits of the study area are discussed here under.

3.2.1 Banded Gneiss

These formations were found around Rangapura (Plate: III, Fig: a), Tadga, Bandre and Shivani villages. General strike trend of the banded gneiss ranges from N10°W to N 40°E and dipping 30 to 73° towards East. Some ultramafic enclaves were intruded within the banded gneiss. The rock is composed of phenocrysts of minerals. Banding arises from segregation of the various minerals, typically into dark and light coloured layers. Individual bands are commonly 1 mm to 1 cm thick. Gneiss is defined by its texture, or arrangement of mineral grains, rather than by its mineral composition. However, the term gneiss is often taken to imply a mineral composition of granite type, dominated by quartz and feldspar. Most gneiss is formed by re-crystallization of pre-existing rock during intense regional metamorphism. Shear stress present during such metamorphism causes formation of gneissic banding, although the exact mechanisms of this process are not well understood. Gneisses typically occupy large areas within the high-grade cores of regional metamorphic belts.
3.2.2 Conglomerate

The conglomerate formations are observed around Kudlur, Koratigere, Nagavangala, Virapura, Hosur and Hebbur villages. A poorly sorted conglomerate rock consisting of individual fragments that have become cemented together and also consisting of rounded fragments. This formation consists of both Para-conglomerates and Ortho-conglomerates. Para-conglomerates (a matrix-supported rock that contains at least 15% sand-sized or smaller grains (<2 mm) the rest being larger grains of varying sizes) and Ortho-conglomerates, a grain-supported rock that consists primarily of gravel-sized grains (~256 mm) with less than 15% matrix of sand and finer particles.

3.2.3 Channagiri Ultramafic-Mafic complex

Channagiri Ultramafic-Mafic complex / Hegdale gudda formation consists of Vi-Ti Magnetite, chromite, quartzite and Limestone. Hanumalapur Complex is a part of Channagiri ultramafic complex which comes under NW part of the study area. Hanumalapur Complex is one of the several mafic-ultramafic complexes (located in the western Dharwar Craton between latitude 13° 45′ - 13° 55′ N and longitude 75° 50′ - 76° 10′ E). The western part of the area is composed of a portion of the south-eastern part of the late Archean Dharwar Super Group (3000-2500 Ma) of the Shimoga basin, and the eastern part is occupied predominantly by a granite-gneiss terrain (~3000 Ma). These are separated by a north-easterly trending fault plane, (Chadwick et al, 1988) as the Main Eastern Boundary Fault. These complexes comprise bodies exposed near Ubrani, Tavarekere, Masanikere and Hanumalapur in the western part of the area, and belong to the Hegdale Gudda Formation (HGF), while the Shivani, Gijikatte, Baktanakatte, Basavapura, Burudekatte and Rangapura (Plate: IV, Fig: a) occurrences, which are mostly ultra-mafic in composition, occur enclosed in the basement gneiss in the eastern part of the area. Channagiri Ultramafic-Mafic complex is highly metamorphosed, highly altered and number of regional scale fractures and linear features exists. These features play vital role in terms of infiltration of water and recharge of groundwater.
The Hanumalapur Complex forms a north-south trending body about 5 km long which ranges in width from 200 m to 1 km, dipping 40°-70° to the east, and being sandwiched between the homogeneous late Archean tonalitic-granodioritic rocks. The comprehensive study has indicated that, among the bodies examined here, only the Hanumalapur offshoot of the HGF has provided evidence of a potential ore-level PGE occurrence so far. Whether the eastern bodies are of the same age as those representing the HGF is not clear from the available data, but the observed field relationships suggest that these are younger than the surrounding gneiss. Contacts between the bodies and gneisses are usually sheared and the ultramafic bodies themselves are highly altered and no chilled contacts have been preserved. A distinctive feature of the eastern ultramafic bodies, as opposed to the westernmost ones, is the absence of titanomagnetite seams, while instead they commonly host chromitite bands. Disseminated chromite has been encountered in the Hanumalapur Complex.

The Complex has experienced metamorphism from upper green-schist to lower amphibolite facies accompanied by corresponding deformation, processes which have destroyed the original textures and primary minerals. The eastern contact of the body is almost vertical and highly sheared, while the western one is not exposed. The body itself is also sandwich-like, the western and eastern sides being composed of gabbroic rocks followed inward by magnetite-rich layers, while the central part is mainly composed of ultramafic rocks, the chief constituent minerals of which are aluminium-rich chlorite, amphibole and iron chromium oxide. The last-mentioned mineral is at present chromium-rich magnetite, although it was originally chromite, relicts of which are encountered in the cores of the grains in places, thus indicating that this rock originally contained disseminated chromites.

3.2.4 Ultramafic enclaves

The occurrences of scattered Ultramafic enclave bodies have been reported by earlier workers (Alapieti et al., 2008). These ultramafic enclaves are situated around Rangapura, Shivani, Bannur, Bandre, Gadi-giriyapura, Gijikatte and also SE part of the study area.
The general trends of discontinued ultramafic enclaves are S30°E strike orientation, located near Guddadahalli and Dasarahalli villages. Generally, these enclaves are intrusive type of formation with very low silica content, high FeO, low potassium, and are composed of usually greater than 90% mafic minerals (dark coloured, high magnesium and iron content). There are mainly three types of ultramafic rocks such as intrusive ultramafic rocks, volcanic ultramafic rocks, ultrapotassic ultramafic rocks. Intrusive ultramafic rocks are often found in large, layered ultramafic intrusions where differentiated rock types often occur in layers.

3.2.5 Granite (Sensu Lato)

Granite is a common and widely occurring type of massive (lacking internal structures), compact, intrusive, felsic, rock compare to gneissic granites (Plate: IV, Fig: b) without primary porosity and very less of secondary porosity as such they tends to have lesser degree of weathering, intensity of fracturing and jointing. Granite has a medium to coarse grained or granum texture, occasionally with some individual crystals larger than the groundmass forming a rock known as porphyry. These granites bodies are dark grey in colour, depending on their chemistry and mineralogy. This granite bodies approximately consists of 25 to 30% quartz, 35 to 45 % of feldspar, 3 to 6 % mica and minor amount of Apatite minerals, which is an important fluoride bearing minerals. In the study area magma under granulite facies; Granite (Sensu Lato), these bodies in the upper crust originated as partial melts in the mid to lower crust. Their formation involves four separate, but inter-related processes: generation, segregation, ascent and emplacement. Massive grey granites bodies were found in the linear ridges and flat land areas near Hanni and Shanaboganahalli villages.

3.2.6 Limestone

Small patches of limestone and dolomite outcrop were found within the Channagiri Ultramafic-Mafic complex (north part of Bukkambudi and Haralahalli villages) and also Kurgudda formation. Limestone often contains variable amounts of silica in the form of
chert or flint, as well as varying amounts of clay, silt and sand as disseminations, nodules, or layers within the rock. There is a possibility of variation of calcium and magnesium content in the groundwater near by limestone and dolomite outcrops.

3.2.7 Migmatites and granodioritic to tonalitic gneisses

Low laying part of the study area consists of Migmatites and granodioritic to tonalitic gneisses (Plate: V, Fig: a). These formations are underlined by red soil, mixed soil and black cotton soil, and also thick brownish-sand with clay deposits near confluence point of Shivani tributary and Vedavathi river (Plate: VI, Fig: b), 3km NW of Chawla Hiriyr village. It is a very high grade metamorphic rock that has been subjected to such high temperatures that it has partially melted and swirled banding. It is intermediate between the metamorphic and the igneous rocks. The light coloured minerals have undergone melting and flow. The dark coloured minerals have been contorted by flow. Migmatites form under extreme temperature conditions during pro-grade metamorphism, where partial melting occurs in pre-existing rocks. The migmatites of the area is typically plagioclase dominant mineral which forming tonalite and granodiorite compositions.

3.2.8 Quartzite

The quartzite bodies are located in the western part of Thimmapura, Jaladhihalli, Siragalipura, Kenchapura, Haronahalli and Basavapura. Some scattered outcrops are located within Channagiri Ultramafic-Mafic complex, which belongs to Tuppadahalli formation; It is a hard, metamorphic rock which was originally sandstone. Sandstone is converted into quartzite through heating and pressure usually related to tectonic compression within orogenic belts. It is white to grey in colour, These quartzite often occur in various shades of pink and red due to varying amounts of iron oxide. Other colours are commonly due to impurities of minor amounts of other minerals. In true metamorphic quartzite, also called meta-quartzite, the individual quartz grains have recrystallized along with the former cementing material to form an interlocking mosaic of
quartz crystals. Minor amounts of former cementing materials, iron oxide, carbonate and clay, are often re-crystallized and have migrated under pressure to form streaks and lenses within the quartzite. Virtually all original textures and structure have usually been erased by the metamorphism. Quartzite is very resistant to chemical weathering and often forms ridges and resistant hilltops. The nearly pure silica content of the rock provides little to form soil from and therefore the quartzite ridges are often bare or covered only with a very thin soil and little vegetation.

3.2.9 Tonalite

The tonalite are found in the adjacent portion of Channagiri Ultramafic-Mafic complex. It is an intrusive type of igneous and plutonic rock, with felsic composition. Tonalite of the study area consists of 10% Feldspar or less alkali feldspar, >20% Quartz, Amphiboles and pyroxenes are common accessory minerals. Tonalite is sometimes used as a synonym for quartz diorite, however the current IUGS classification defines tonalite as having greater than 20% quartz and quartz diorite with from 5 to 20% quartz, minor amount of biotite and apatite minerals. General strike orientation of tonalite formation of the study area is N 30° W to N 10° E with rolling dip towards east and west direction. (Ranges from 14°E to 70°E and 35°W to 80°W).

3.2.10 V-Ti Magnetite

Thin linear patches of V-Ti Magnetite are found within the Hanumalapur Ultramafic Complex. Vi-Ti Magnetite was found in the Masanikere, Tavarekere, Ubrani, Nellihankalu and Hanumalapura. An unusually thick sulphide-poor mineralized zone enriched in platinum-group elements (PGE) is described in the Hanumalapur Complex. This promising occurrence was discovered by Devaraju et al. and Alapieti et al. (1994) from outcrops upon re-evaluation of vanadium-bearing titaniferous magnetite deposits in the early 1990's. The State Department of Mines and Geology and the Geological Survey of India have repeatedly prospected for both V-Ti magnetite and chromite deposits in the area.
Fig. a: Typical disconnected outcrops of banded gneiss near Rangapura.  
(Courtesy: Prof. T.C. Devaraju)

Fig. b: Sharply pointed blocky outcrop of ultramafite (coarse grained meta-peridotite) on the south of the road between Burudekatte and Basavapura  
(Courtesy: Prof. T.C. Devaraju)
Fig. a: Elegant mineral banding/layering displayed by ultramafite near Rangapura.  
(Courtesy: Prof. T.C. Devaraju)

Fig. b: Massive granite body with red soil (0.3km south of Mugilhalli)
Fig. a: Contact between Pink granite & Meta-volcanics, Location: Confluence Point of Shivani River and Vedavathi River

Fig. b: Chitradurga schist belt near Nelihankalu village
Fig. a: Meta-volcanic out crops near Durvigere village

Fig. b: Thick brownish-sand with clay deposits near confluence point of Shivani river and Vedavathi river (3km NW of Chawla Hiriyr village)
3.3 Lineaments of Shivani watershed

Lineaments are planar features intersecting the superficial parts of the earth's crust. The disposition of these lineaments can be in different angles. The trend of such lineaments can be traced on the surface of the earth as linear features. These linear features connect the surface hydrological processes to the deep sub-surface inter connections. The trend lines of these lineaments on the land surface indicate sudden change in topography, soil type, vegetation anomaly, existence of springs amidst dry area. It is easy to trace the lineament zones by interpretation of satellite imageries or aerial photographs. Digital Remote Sensing, Geophysical Survey, Tracer Studies and Exploratory drilling process are the types of survey required to study the aquiferous lineaments. The mapping of lineaments and structural features commonly takes place in a digital environment using either image processing systems or GIS. In the present study, the lineaments are extracted based on three categories such as hydro-geological significance, vegetation evidence and alignment with drainage and topography. The study area has hard crystalline and metamorphosed rocks and devoid of primary porosity. The occurrence, storage and movement groundwater in hard rock terrain is mainly controlled not by lithology alone, but by a variety of other parameters including fractures, lineaments, discontinuity, permeability extent of weathering and drainage pattern.

The most obvious structural features that are important from structural point of view are lineaments. They occur as linear alignments of structural, lithological, topographic, vegetational, drainage anomalies etc. Lineament is defined as a large-scale linear feature, which expresses itself in terms of topography of the underlying structural features. In other words lineaments defined as a regional scale linear or curvilinear feature, pattern of changes that can be identified in a data set and attributed to a geologic formation or structure. From the groundwater point of view such features may include, valleys controlled by faulting and jointing, hill ranges and ridges, displacements and abrupt truncation of rocks, straight streams and right angle off setting of stream courses (Ramesh, 1990). The linear features can be measured and treated quantitatively like measurements.
of other geological properties, but it is necessary to use formal statistics that reflect the circular nature of the directional data (Gaile and Burt, 1980; Gumbel et al., 1953; Mardia, 1972).

Lineaments provide the pathways for groundwater movement and are hydro geologically very important (Sankar et al., 1996). Lineaments are important in rocks where secondary permeability and porosity dominate and inter-granular characteristics combine in secondary openings influencing weathering, soil water and groundwater movements. The fracture zones form an interlaced network of high transmissivity and serve as groundwater conduits in massive rocks in inter-fracture areas. The areas falls under intersection of lineaments with structurally disturbed areas are considered as good groundwater potential zones. The combination of fractures and topographically low grounds can also serve as the best aquifers horizon (Subba Rao, 1992). The lineaments follow the stream courses and intersecting lineaments are considered as good potential zones of groundwater targeting, as they reflect high porosity and hydraulic conductivity of the underlying materials (Sahai et al., 1991, Subba Rao and Prathap Reddy, 1999).

The lineaments of the study area has been interpreted from satellite images using edge enhance technique (filtering technique) of ERDAS Imagine 8.5 Image processing software. These lineaments are trending in the directions of N 10° to 50° W, N 10° to 70°E. The length of the lineaments extends few km to several kilometres. Main linear features in the terrain are metamorphic and igneous rock trend lines, valleys, streams, alignments of gaps in the ridges and topographic sags. According to Strahler (1964) Bifurcation ratio (Rb) values ranging between 3 and 5 are considered to be characteristic of the watersheds, which have suffered minimum structural disturbances. Where as, the value of Bifurcation ratio greater than 5 is considered as maximum structural disturbance area. However, in the study area the Rb value for 4th and 5th order streams is 14. It implies that the area between 4th and 5th order stream is significantly affected by structural disturbances. These structurally disturbed areas with lineaments are very important from the groundwater water recharge point of view. The prominent linear features / lineaments and structural disturbances regions are well represented in the Fig: 3.3.
Fig: 3.3 SHIVANI WATERSHED: LINEAMENT MAP

Lineaments
Structurally Disturbed areas (Rb values is 14 in 4th and 5th order stream)
Natural Tanks