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भारत सरकार
GOVERNMENT OF INDIA
भारतीय भूवैज्ञानिक सर्वेक्षण
GEOLOGICAL SURVEY OF INDIA

आंध्र प्रदेश के वाई.एस.आर. कडपा और अनंतपुर जिलों के भागो में विशेष जोर देने के साथ जल में यूरेनियम संदूषण का भू-पर्यावरणीय मूल्यांकन:

GEO-ENVIRONMENTAL APPRAISAL IN PARTS OF Y.S.R KADAPA AND ANANTAPUR DISTRICTS, ANDHRA PRADESH WITH SPECIAL EMPHASIS ON URANIUM CONTAMINATION IN WATER

धरातल पत्रक क्रमांक: 57 जे/3 और 57 जे/7
Toposheet Nos.: 57J/3 and 57J/7

मद संख्या: एम4 बी ईन् वी/एनसी/ एस आर/2022/42660

Item No.:M4BENV/NC/SR//2022/42660

कार्यसत्र 2022-2023 का प्रतिवेदन
Report for field season 2022-23

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सितम्बर, 2023
September, 2023

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Toposheet No. 57J/3 and 57 J/7
Field Season: 2022-2023
(FSP ITEM NO.: M4BENV/NC/SR//2022/42660)

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Toposheet No. 57J/3 and 57 J/7
Field Season: 2022-2023

(FSP ITEM NO.: M4BENV/NC/SR//2022/42660)

By

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Abstract

The Geo-scientific studies could contribute for immense societal importance, under the aegis of Theme 3 “Public Good Geosciences” of VAQ. A project on Geo-environmental appraisal in parts of Y.S.R Kadapa and Anantapur districts, Andhra Pradesh with Special Emphasis on uranium contamination in water was carried out in pursuance of the Field Season Program 2022-2023 (Code no. M4BENV/NC/SR//2022/42660) of Quaternary and Environmental Geology division, Southern Region, Hyderabad with collaboration of Central Ground Water Board, southern region. The work was executed over an area of 1000 sq. km in parts of Survey of India toposheet nos. 57 J/3 and 57 J/7 on 1: 50,000 scale.

The objective of the work is (i) Spatial distribution of Uranium contamination with its zonation. (ii) Vulnerability index map (showing high, moderate, low and contamination free zones). (iii) Impact of mining activities in the area (iv) To suggest possible mitigations.

The study area is covered by the Papaghni and Chitravati Groups of Cuddapah Supergroup, which rest unconformably over the PGC and Dharwars. The older metamorphics, which mainly include amphibolites, biotite schist, meta gabbro, sillimanite chlorite schist and pyroxenite and they occur as xenoliths of varying dimensions within the major Peninsular gneissic complex, further the amphibolites and biotite schist occur as a zone of enclaves in the migmatite of the Peninsular gneissic complex. The Veligallu schist belt rocks comprise of small bands of quartz-muscovite-sillimanite schist. It occurs as small rafts within the grey hornblende-

biotitegranite gneiss and pink granite rocks of PGC which are in turn intruded by thin quartz veins and dolerite dykes

Geomorphological map of the study area reveals different landforms of structural origin (Dissected hills and valleys, ridge); denudational origin (residual hill, residual mound, low to moderately dissected hills, pediment corestone tor, valley fill, pediment, pediplain); anthropogenic origin (active Mining/quarry, mine dump, tailing pond, abandoned quarry).

In the spatial distribution maps of elements of the soil shows that Al_2O_3, FeO, MgO, TiO_2 values are high above the crustal abundance. HREE distribution is high with compare to LREE. Trace elemental and heavy metal distribution is low to moderate with relative to average abundance. REE also moderately high due to the underlying granitic lithology. Based on the weathering indices pattern, it is found that soil samples from Regolith are enriched in elements than that of C-horizon developed over the Cuddapah super group rocks. No significant contamination with respect to REE and trace elements have been identified in the study area.

Water quality index of the study area shows existence of poor water quality in the study area for pre monsoon; few scattered patch of area shows good water quality conditions. while post monsoon majority area falls under the Good water quality conditions. Ulimella,East of Pulivendula , Gotur, Peddajuttur,Nallacheruvu palli, N. palagiri, Pendaluru, pamaluru, Bakkanagari palli and Vepamampeta villages have very poor water quality which is unsuitable for drinking purposes.

Pollution index of ground water shows that clusters of zones in and around Ulimella,East of Pulivendula, Gotur, Peddajuttur,Nallacheruvu palli,Gundi palli, Pendaluru, pamaluru, Bakkanagari palli and Vepamampeta villages areas. Insignificant pollution zone is observed from the Southern part of the study area. This indicates that the quality of groundwater in the study area is mainly influenced by the source of geogenic origin, but it is subsequently modified by the effects of anthropogenic sources.

The hydro-chemical facies of the groundwater in the study area indicate that the dominant water facies is Magnesium bicarbonate to mixed type in Pre monsoon and Post-monsoon respectively. The water quality of 80% of the groundwater samples is due to the result of intensive soil-water-rock interactions, followed by mineral dissolution, ion exchange and evaporation processes in the groundwater system, which also indicate that the geogenic origin is the dominant controlling factor of the groundwater chemistry in the present study area.

Sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and Kelly's ratio (KR) indicated that most of groundwater samples were safe for the irrigation use. sodium percent (Na%) Corrosivity ratio (CR), soluble sodium percent (SSP) shows North eastern part of the area is not suitable for irrigation. However, magnesium ratio indicated that the majority of the study area were unsuitable for irrigation use. Results of salinity hazard index diagrams shows that 80% of the samples from PRM and POM are falls under water type C3-S1 (high salinity—low SAR) and 10% of the samples fall in C4-S1 and C4-S2(Very high salinity –low SAR). Hence, the water of these sites cannot be used as irrigation water for the soils with limited drainage.

In soil samples high Uranium concentrations zones are observed around the Dugganagaripalli, Nagur, Achavelli, Mabbuchintalapalli, tummalapalli, timmapuram peta, Nalupureddipalle, udumulakurthi, Kondareddypalle, Lakkasamudram, Batrepalli, and Vepamammeta. These areas are mostly occupied by the Cuddapah supergroup group and Peninsular gneissic-II.

The Bar graph shows 04 nos. of both Regolith and C- Horizon samples area taken having uranium values are ranging from 11.41 ppm to 32.98 ppm in Regolith and C- horizon having 11.3 to 29.6 ppm. These values are suggested that regolith samples is more prone for uranium values in respect to C-horizon due weathering and dilustion of uranium bearing minerals in PGC-II group of rocks. While Cuddapah group of rocks having 4.68 to 29.7 ppm in Regolith samples and 2.91 to 40.86 ppm in C-Horizon. These values due intercalated package of dolomite, shale, dolostone hosted the lithological control of Uranium mineralistaion in that areas. The Bar graph shows U values in nearly 60 of the regolith samples are greater than that of C Horizon. It may be suggested that regolith is more prone with compare to the c-horizon. High uranium values repoted in SP 14 (Pernapadu area) underlained by Tadipatri shales and SP6 (Oddilapalli area) over on the PGC-II group of rocks.

Geo-accumulation index (Igeo) map of uranium reveals that majority of the area is falling under moderaltly contaminated to highly contaminated zones in terms of uranium for soil samples obtained by near Tummalapalli. UCIL, Nallacheruvu, Moilacheruvu, N.Palagiri, Nagur, Kondareddy palli, Gotur, Chandragiri, Dugganagaripalli, Peddajuttur, Gundipalli and Kuppakutlapalli areas due to underlined rocks in the study area . Enrichment factor map of soil and bar graph suggested that significant enrichment in South western part of the study area due to PGC-II group of rocks these may evident to bed rock analytical data uranium. Theses granitoids are the main source for releasing of uranium in ground water due to weathering and fracture/ joints fluoride bearing minerals in these rocks.

In the Ground water samples uranium concentrations are ranging from 0.31 ppb and 1315.52 ppb in PRM water samples with the average value of 35.87 ppb and from 0.01 ppb and 635.71 ppb in POM water samples with average value of 18.83 ppb. 15% of the samples in PRM and 7% of the samples in POM are having concentration beyond permissible limit 30 ppb (WHO 2011) and 60 ppb of (AERB 2007). Higher U values in 3 nos. of water samples during pre-monsoon are falling in the agricultural and grass land over PGC-II in a scattered manner, whereas 3 nos. of water samples during post-monsoon shows higher U values falling over Tadpatri shale of Cuddapah Supergroup and PGC-II in the agricultural land in a scattered manner. The highest Uranium concentration (1315.52 ppb) during pre-monsoon is detected South of Lakkasamudram village. The highest Uranium concentration (635.71 ppb) during post-monsoon is detected near Mabbu Chintala Palle village exceed the maximum permissible limit of (30 ppb by WHO and 60 ppb of AERB).

Anthropogenic activities act as supplementary factor for further elevation of Uranium in the groundwater. Nearly 62% samples exceeds the permissible limits. Excess use of chemical fertilizers, excessive ground water pumping can also cause significant uranium enrichment in pre monsoon ground water samples in POM. Geomorphology, these areas are pediplain areas and land use and land pattern shows most of the areas under cultivation in barren lands and hill slope areas which were converted to cultivate lands. The uranium concentration is often found to be sporadic, uneven and varies with depth. The uneven distribution of uranium in the study area primarily due to variation in mineral assemblage of rocks, anisotropic nature of hard rocks aquifers and associated hydro chemical process.

In the study area Uranium and Thorium concentrations are mostly controlled by geogenic factors which becomes enhanced by anthropogenic sources. Shallow level aquifer mainly effected due to intense activities, especially the over-exploitation of ground water for agricultural irrigation and domestic use can contribute to the problem of declining groundwater levels which induces oxidizing condition that promotes the formation of soluble uranyl carbonate complexes.

As the water level declines, contaminants in the soil, like uranium and arsenic, can mobilize and pollute the water bodies for safe drinking point of view water purifier plants are required for high uranium concentrated areas. During the execution of field work it has been recorded that UCIL plant and UCIL tailing pond near by villagers (Kanampalli, Rachakuntapalli, Bhummayareddypalli, Giddangivaripalli, Mabbu chintalapalli, Tummalapalli, were facing Skin allergies issues and health issues. It is noticed that people are living near to the tailing pond Kanampalli villagers consuming uranium contaminated water in summer due to lack of water which aggravate the Skin allaergies issues while dust received from tailing pond . In adjacent villages to the UCIL (Tummalapalli, Manbbuchintalapalli, Rachakuntapalli) UCIL had established overhead water tanks, solar light facility but regular monitoring and maintenance are required. It is also recommended to install extra filters pertaining to the fluoride and arsenic. Chemical remediation procedures include ion-exchange, defluoridization, precipitation, co-precipitation, and adsorption.Bioremediation methods including the use of biochar, phytoremediation and microbial remediation are appropriate for large areas where water is contaminated by low concentrations of uranium.

In soil, uranium enrichment is not observed while compared to the Thorium which may effect the agricultural activities in the study area as ground water are mostly used as irrigations. Apart from Uranium, Thorium, fluoride and Arsenic, nitrate pollution is noticed in the study area which increases periodically. Phytoremediation technology can be a good option to repair large areas of low concentration of uranium-contaminated soils. For reduction nitrate pollution, less use of nitrogen based fertilizers.

GEO-ENVIRONMENTAL APPRAISAL IN PARTS OF Y.S.R KADAPA AND ANANTAPUR DISTRICTS, ANDHRA PRADESH WITH SPECIAL EMPHASIS ON URANIUM CONTAMINATION IN WATER

(Final report for the Field Season 2022-2023)

(FSP Proposal ID: M4BENV/NC/SR//2022/42660)

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CHAPTER-1

INTRODUCTION:

Uranium is a nephrotoxic element and naturally occurring radioactive metal that occurs in low concentrations in nature, which means people dependent on groundwater containing the element are at a higher risk of impaired renal function and kidney disease. In India, twelve states having the uranium concentrations in ground water beyond the permissible limits (CGWB 2013). The safe levels for uranium in groundwater in India are 30 µg/L as is established by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO) to minimize the risk of these health effects. Groundwater with high levels of uranium is typically associated with Pre-Cambrian rock formations and the alluvium aquifers through which the groundwater flows. Various natural aspects which effect the uranium concentration in groundwater such as bedrock geology, water chemistry, and redox conditions, and anthropogenic sources such as mining activities (uranium, coal, and phosphate rock), nuclear activities, agricultural practices of using phosphate fertilizers, and prevalence of excessive nitrate.

1.1 BACKGROUND:

This proposed work could contribute for immense societal importance, under the aegis of Theme 3 “Public Good Geosciences” of VAQ, Presence of high Uranium in ground water in different parts of the country has been reported by various central, state & research institutions in the last two decades with availability of better analytical facilities. Exposure to uranium through drinking water has been associated with nephrotoxic effects. The concentration of naturally-occurring uranium in groundwater depends on the uranium content of the rocks and the rate of leaching and dissolution processes. The main factors that may drive high uranium concentrations in groundwater are source rocks, oxidation state, water rock interaction and formation of soluble complexes. Anthropogenic factors such as groundwater table decline and nitrate pollution has also been found to further enhance uranium mobilization in ground water. Industrial processes like extraction of phosphorus from phosphate ores to produce phosphate fertilizers, uranium enrichment, uranium mine tailings disposal, and uranium mining and milling to produce uranium oxides also add Uranium in the environment. Besides Uranium, the presence of other major deleterious heavy metal toxins like Lead, Arsenic, Fluoride and Mercury in ground waters of different parts of the country have also been reported. Fluoride and Arsenic contaminated groundwater is widely known global issue affecting millions of people living in several countries.

The Cuddapah Basin in southern India is well known for its rich mineral deposits particularly base metals, asbestos, baryte and uranium. These mineral deposits have great influence on the quality and chemistry of groundwater. Radioactive dolomites occur at two places, viz., Tummalapalle and south of Vemula, crystalline baryte at Vemula and chrysotile asbestos belt confined within Brahmanapalle and Ipatla range. The Tummalapalle uranium ore in the Cuddapah Basin is the largest reserve in the country and the mine started its operation in 2012. The quality of groundwater and soil in Tummalapalle and nearby villages has deteriorated and presence of extremely high levels of trace elements such as uranium, barium, cobalt, lead, chromium and zinc has been detected (Centre for Materials for Electronics Technology-C-MET, Nagaraju, 2014, Sunkata Goswami, 2016), Additionally Pulivendula, Vemula, Brahmanapalle and Ipatla mandals also contaminated by barite and Asbestos mines. Mining operations and mine-waste disposals in these areas may disturb the natural characteristics of groundwater and soil.

The radioactive waste tailings produced by uranium mining activities contains a series of long-lived radionuclides such as uranium (U), radium (Ra), and thorium (Th) isotopes. Therefore, the knowledge of natural radionuclide concentration levels and their mobility in the environment is of great interest in several scientific fields. Over the years, only some work on radioactive food contamination in the environment and its transfer of pathway mechanism to plants, animals and human population has been reported. Several researchers have screened fast-growing, high – biomass accumulating plants, including agronomic crops, for their ability to tolerate and accumulate trace elements in their shoots (Sunkata Goswami, 2016).

The restricted water resources are inconsistently distributed, and there exists vast special and temporal variability within the quantity of rain. Despite these variations, trace elements contamination is reportable in all the environmental condition regions of India, i.e. semi-arid, tropical wet, dry and humid climatic zones. Aquifers in as many as 18 States in the country are contaminated by uranium, whose presence in drinking water has been linked to chronic kidney disease by several studies, a recent study has shown. Uranium is a radiotoxic and chemo toxic trace element. Intake of uranium can cause chemical as well as radiological toxicity which usually affects the kidneys (through ingestion from water or food) and the lungs (through inhalation). Zamora et al (1998) had reported cases of kidney disorders due to ingestion of drinking water containing uranium as high as 780 ppb. Garshasbi et al (2005) reported the uranium concentration in seawater of Caspian Sea and Persian Gulf to be around 6.12 ± 0.18 ppb and 3.53 ± 0.1 ppb. Large amounts of solid wastes (tailings) resulting from the exploitation and treatment of uranium. It is one of the most frequent pollutants of groundwater and surface soils. Since uranium is chemically toxic to kidneys and insoluble compounds are highly carcinogenic. The uranium-contaminated soils may represent significant risks to human health, primarily via food chain.

Parts of Andhra Pradesh State (covering areas in and around Tummalapalle uranium deposit, Vemula Mandal of YSR Kadapa district) is a target area for study with special emphasis on Uranium. The proposed area forms part of Cuddapah & Anantapur districts, Andhra Pradesh. The crescent-shaped Cuddapah Basin of Andhra Pradesh, south-eastern Peninsular India, has a maximum width of 145 km (in the middle) and 440 km long and is exposed over an area of 44,000 sq. km. On the western margin of the basin the undisturbed Proterozoic sediments rest on an Archaean gneissic complex enclosing the greenstone belts of Kadiri, Veligallu and Gadwal with a profound nonconformity. Lithostratigraphically, the Cuddapah Basin is divided into Papaghni, Chitravati, Nallamalai and Kurnool groups from base to top. Papaghni and Chitravati Group of rocks are exposed in the Pulivendula, Tummalapalle, Brahmanapalie-Vemula area. Tummalapalle uranium deposit is located in the middle of the south-western margin of Kadapa basin. Vempalle carbonate rock Formation is the host rock of uranium mineralization, forms the upper part of papaghni group of the rocks and is underlain by Gulcheru quartzite. The radioactive minerals identified in the ore zone are pitchblende, coffinite, and U-Ti complex Coffinite is fine grained and associated with pyrite. Other associated minerals are pyrite, chalcopyrite, molybdenite and collophane.

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In Indian context lead, mercury, chromium, cadmium, copper, aluminum and uranium along with arsenic are of major concern. The bioaccumulation and very slow rate of excretion of many of the trace elements from human body make them dangerous and deadly. The prolong exposure to these elements' contaminations have severe health concerns with several chronic degenerative diseases. In the light of the above background information a collaborative study on Uranium contamination in ground water in India was proposed to take up by CGWB and GSI with joint agreement on As, Pb, F and Hg under the study through MoU.

1.2 OBJECTIVE:

The primary objective of this work is a) Spatial distribution of Uranium contamination with its zonation; b) To make vulnerability index map; c) Study the impact of mining activities in the area.

1.3 LOCATION AND ACCESSIBILITY:

The study area is covering in parts of Cuddapah and Anantapur districts in Andhra Pradesh and geographically bounded between latitudes 14°15'00" N to 14°29'00"N and longitudes 78°06'00"E to 78°27'00"E falling in the parts of Survey of India (SOI) toposheet nos 57J/3 & 57J/7 (Fig.1.1). The work was executed over an area of 1000 sq. km on 1:50,000 scale for one field season. The area is located approximately 420 km east-southeast of Hyderabad. Pulivendula, a tehsil in Cuddapah district, is the nearest town to this area. Pulivendula is easily accessible via a four-lane road connecting it to Cuddapah. For those traveling by train, the closest railway stations to Pulivendula are Muddanuru town and Cuddapah is the nearest airport. The interior parts of the area have well-developed connectivity, with both metal and gravel roads. All the neighboring villages are linked to Pulivendula through double roads, various metalled roads, and unmetalled roads. Some significant villages in the vicinity include Vempalli, Vemula, Tummalapalle, Rachkuntapalle, Vepamanipeta, Palgiri, Goturu, and Ulimella.

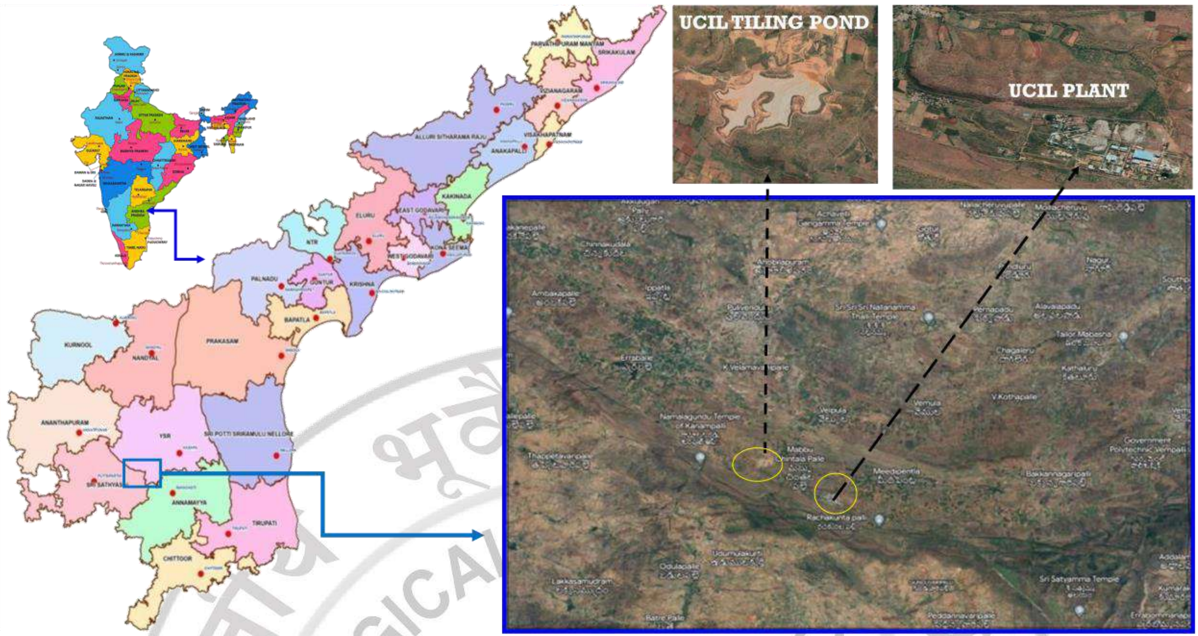

Fig. 1.1: Location map of the study area along with UCIL Plaaant and Tailing Pond, YSR Kadapa & Anantapur district, Andhra Pradesh.

1.4 PHYSIOGRAPHY:

The topography of the area is characterized by an undulating plain in the northern part, the Dorigallu and Gorivikanuma hill ranges in the southern part, and a series of hillocks in the central region, along with a few isolated mounds. This topography is a reflection of the underlying geology, creating a hilly region with parallel flat-topped ridges that trend from east to west. The quartzite, traps, and limestone formations form prominent ridges that are more resistant to erosion, while the shale, which is easily eroded, occupies the flat lowlands to the north of the area. This results in a vast undulating terrain representing an ancient peneplained surface with a gentle slope from west to east, punctuated by small residual hills scattered throughout. The highest elevation in the area is 793m above Mean Sea Level (M.S.L) at Ellakonda in the south, while the lowest point of 226 m above Mean Sea Level (M.S.L) is observed near Chagaleru.

The easternly flowing Moganur Eru River forms the main drainage of the area. Besides this, there are a number of seasonal streams draining into some large tanks situated near Lakshasamudram, Kottapalli, Odulapalli, Bandamadapalli, Vemula, Pendluru, Nallacheruvupalle etc. The hill ranges exhibit sub-parallel drainage pattern whereas the plains and isolated hillocks show sub dendritic and sub-parallel drainage pattern. Sub dendritic and sub radiating drainage patterns with channel filled are mostly prevalent in the area.

1.5 CLIMATE AND RAINFALL:

The climate of the area is generally characterized as hot and dry during the summer season, except for the period from June to September when the southeast monsoon occurs. From February to the middle of June, the temperature gradually increases. During the peak of summer, temperatures can reach between 45-47°C, while in winter, they range from 16-18°C. The average annual rainfall in the area is approximately 1220 mm. Relative humidity during the monsoon season can reach up to 70 percent, whereas during the dry summer and winter, it ranges from 20-25 percent. The prevailing wind direction is typically from south to north. In summer, the winds blow from east to south, while during the monsoon, they shift from south to east. The climate conditions in the area contribute to relatively rapid chemical weathering and the decomposition of organic matter. The short duration of the rainy season also leads to significant surface erosion, particularly since much of the area lacks protective vegetation.

1.6 FLORA AND FAUNA:

The residual hill mounds and pediments in the area are predominantly covered with bushes, scattered Babul trees, and patches of grass, creating a pastureland-like environment. In the southeastern part of the area, vegetation is relatively denser, supporting various plant species. Ferns are commonly found along the banks of streams. Due to the rocky terrain, the trees in the area generally have a height of less than 14 meters and a girth not exceeding 1 meter. The forests in the area are classified as tropical mixed and deciduous. Main species include Neem (Margosamargosate), Prosopisspicigera (Chavi), Euphorbia antiquorum (Pedda Ja-mudu), Pterolobiumindicum (Korinda), and Kher.

The fauna in the area includes species such as wild boars (*Suscristatus*), Sambhar (*Cervus unicolor*), antelopes, deer (*Cervusduvancelli*), foxes, wolves, monkeys, and hares (*Lepus reficaudatus*). However, the numbers of these herbivores, particularly Sambhar and spotted deer or chital, are limited. Among the rodent population, common jungle hares and porcupines are frequently encountered. Birds commonly observed in the area include magnificent peafowls and peacocks, jungle fowls, pigeons, parrots, partridges, geese, and doves. During the winter months, migratory birds such as ducks and teals are seen in the area.

1.7 PREVIOUS WORK:

As per the reports of the Andhra Pradesh Pollution Control Board (APPCB), the groundwater near the Tummalapalle Uranium Corporation of India Limited mines in Andhra Pradesh has been found to have uranium concentrations ranging from 690 to 4000 ppb. This has resulted in the groundwater in villages such as Mobbuchintalapalli, K KKotta, and Kannampalli being severely affected due to high alkalinity and uranium concentration. The mining activities carried out by UCIL using the alkaline leaching method for producing sodium di-uranate are believed to be the primary cause of these high concentrations.

The Centre for Materials for Electronics Technology (C-MET) has also reported uranium concentrations of up to 308.5 ppb in the area. Additionally, a study conducted by Nagaraju in 2014 found high levels of uranium in soil and plants around the Tummalapalle region. Indoor radon/thoron concentrations in the area were reported by Reddy et al. in 2003. In a study conducted by Singh et al. in 2002 in the Palnadu sub-basin, which is adjacent to the proposed area, uranium concentrations ranging from 0.5 to 410 ppb were detected in groundwater samples. Another study by T. Raghavendra et al. in 2013 used laser fluorimetry to analyze groundwater samples in the region, revealing uranium concentrations ranging from 0.6 to 521.15 ppb. The Atomic Minerals Directorate (AMD) has reported high uranium concentrations of up to 2,618 ppb in areas such as Lambapur, Peddagattu, Chitrial in Nagarkurnool and Nalgonda districts of Telangana. These concentrations far exceed the permissible limit of 30 ppb. These reports indicate significant concerns regarding elevated uranium concentrations in groundwater and soil in the mentioned areas, raising potential environmental and health risks

1.8 PRESENT WORK:

In pursuance of the Field Season Programme vide FSP code: M4BENV/NC/SR//2022/42660 *for* FS: 2022-23, Quaternary and Environment Geology Division, GSI, Southern Region, Hyderabad, undertook a research project “Geo-scientific studies aim to address the significant issue of elevated uranium concentrations in Y.S.R Kadapa and Anantapur districts in parts of toposheet nos 57J/3 & 57J/.

This project includes multiparametric study like collection of groundwater as a drinking water source and its vulnerability to element enrichment, the study will focus on collecting pre-monsoon and post-monsoon groundwater samples (from borewells, dug wells, and hand pumps) as well as surface water samples from potential areas by CGWB and Soil samples and soil profile studies from the R and C horizons will also be carried out to understand the depth and dispersion pattern of uranium in the soil, Petrochemical samples, petrographic section studies, EPMA and SEM studies by GSI. The primary objective is to conduct comprehensive geo-scientific investigations during one field season to demarcate zones with uranium contamination, identify uranium-bearing minerals responsible for the contamination, and assess the role of geological structures, if any, in the process. Remedial measures will be suggested based on the findings of the study.

Spatial analysis using thematic maps such as geomorphological maps, land use land cover maps, and drainage maps in a Geographic Information System (GIS) will be conducted to establish the spatial relationship between geogenic factors and potential health impacts, if any. The goal is to investigate the uranium concentration levels in groundwater used for drinking purposes and determine any potential health effects on the local population. The study will involve various components, including drainage network analysis, lineament studies, soil profile analysis, and chemical analysis of bedrock, soil, surface water, and groundwater. Once the project is completed and geological causes are established, an intensity map of uranium contamination will be prepared, serving as a guide for local authorities. The broader focus is to understand the causes and impacts of the problem on the local society and provide recommendations for remedial measures.

Table-1.1: Nature of quantum of work carried out during FS:2022-23

Sl. No	Nature of work	Total workload envisaged	Work completed during FS 2021-22
1	**Remote Sensing Studies** a) Preparation of Geomorphological, Landuse / Landcover and lineament map. b) Preparation of digital elevation Model. c) Preparation of Drainage map.	1000 Sq.km	1000 Sq.km
2	**Sampling (**Nos.)		
	(a) Water Sample (Pre & Post-monsoon) *	400 Nos.	399 Nos.
	(b) Petrochemical samples (PCS/BRS)	30 Nos.	30 Nos.
	(c) Soil samples	100 Nos.	100 Nos.
	(d) Soil profile studies		
	Regolith	20 Nos.	20 Nos.
	C -Horizon	20 Nos.	20 Nos.

	(e) Petrological samples* (f) EPMA (g) SEM	20 Nos. 10 Nos. 10 Nos.	30 Nos. 10 Nos. 10 Nos.
3	**Chemical Analysis** Major ions and trace elements of soil nd pcs samples	570 Nos.	569 Nos

*Water samples will be collected and analysed by the Central Ground Water Board (CGWB).

Table-1.2. Field stay details of Field Officers & Supervisory Officer.

SL. No.	Name of the officers	No. of days spent in Field
1	Smt. Anwesha Roy, Sr. Geologist (PT)	33
2	Shri Manga Raja Rao Bevara, Geologist, (PT)	30
3	Ms. Aditi Biswas, Geologist	26
4	Shri Shailendra Kumar Singh, Director (PT)	5

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CHAPTER-2

THEMATIC MAPS

(DRAINAGE, GEOMORPHOLOGY, LINEAMENT, LANDUSE-LANDCOVER)

2.0 INTRODUCTION:

As a part of the Geoscientific investigation, various thematic maps were prepared to understand multi-thematic aspects of the study area as a part of the pre-field preparation concerned. These include the Drainage map, Geomorphological map and Lineament map, Land use and Land cover map, and Digital elevation model for correlating the chemical analysis results of different sample media, a set of thematic maps were prepared/compiled on a scale of 1: 50000. It also includes consultation of previous work related to geology and mineral occurrence in the area.

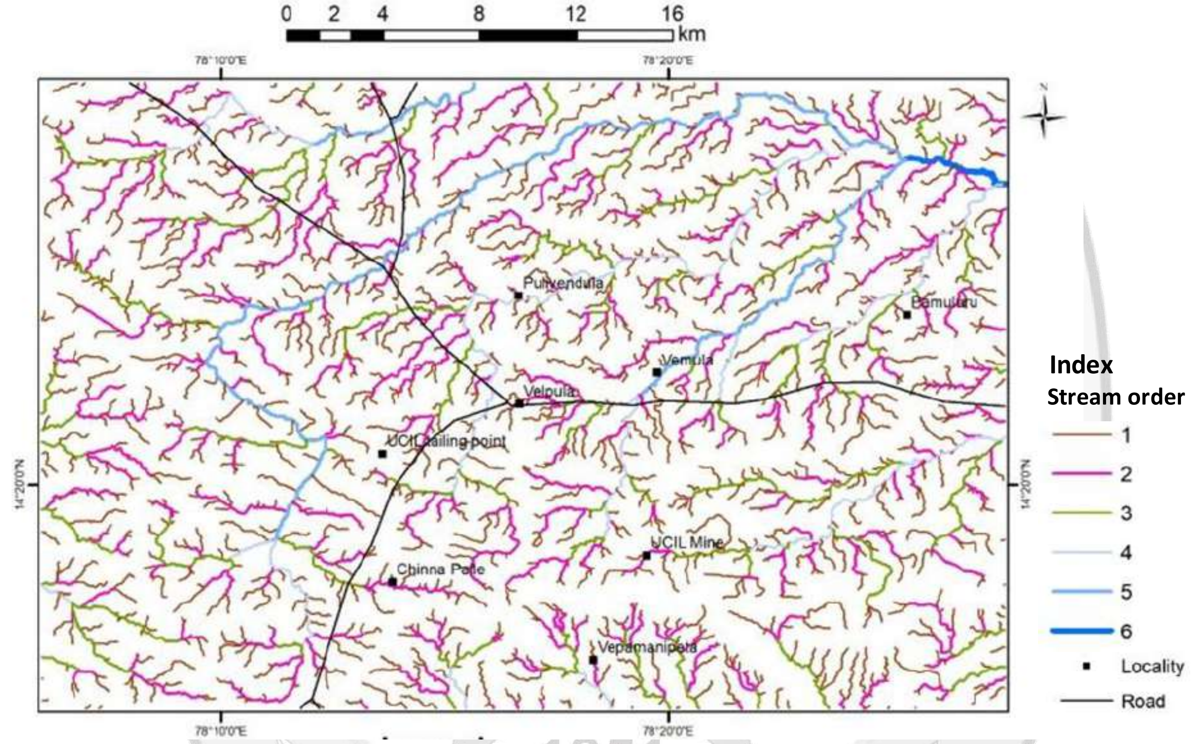
- Preparation of a drainage map (1:50,000 scale) is the most essential for planning site selection and executing the sampling which forms the base for preparing distribution maps of various elements analyzed.
- Compilation of geological map including major lithologies on 1:50,000 scale of toposheet no. 57J/3 and 57J/7 to determine the structural and lithological relationships for understand the geological setup of the study area.
- Compilation of geomorphological and lineament map to understand morphological and structural features in the area.
- Preparation of land-use and land cover map for understanding natural features (forest cover) barren lands, Buildup areas, manmade features like urbanisation and mine developements in the study area.
- Preparation of hillside and contour map to understand relief of the area with respect to the digital elevation model, natural slope control by geomorphological feature.

- To understand multi-thematic aspects of the study area like geology, drainage, geomorphology, and land use pattern and for correlating the chemical analysis results of different sample media to give a brief idea about the study area in various aspects.

2.1 DRAINAGE:

The classification of drainage pattern is important as it gives an idea of topographic and geologic controls on water flow and sediment accumulation. The drainage pattern is highly dendritic having high drainage density. The dendritic pattern develops in areas where the rock beneath the stream has no particular structure and can be eroded equally easily in all directions and most streams have been altered due to the irrigation practices in the area.

Fig.2.1 Draiange map of the Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



2.2 GEOMORPHOLOGY AND LINEAMENTS:

Geology and geomorphology play a prime role in the geogenic mobility and accumulation of elements. It is mainly useful in understanding relief of the area and it is most important inputs in planning for developmental activities in various projects. The scope of geomorphology landform map has increasing utility in various fields of urban geology, watershed management, land and water resources survey, mineral exploration, geotechnical investigation, geo-environmental analysis, active fault studies and seismic hazard micro-zonation. The geomorphological map was prepared using SRTM-DEM, Survey of India Open Series Map of the area as the base map, Google map and existing 1: 50,000 scale geomorphological map generated during the National Geomorphological and Lineament Mapping Project (NGLM) with the help of Bhukosh. The geomorphic units in the area are categorized as landforms are denudational, structural, anthropogenic origin and water bodies in the study area based on the satellite imagery and limited field checks. The image elements drainage characteristics pedogenic and morphogenetic expression authenticated by field checks have been used for identification and mapping of geomorphic units. The geomorphic units have been classified on the basis of differential erosion of rock material, erosion process, weathered zone, relief of the area. Major landforms present in the area include Pediplain - Pediment (75%), moderately to low dissected hills and valleys (20%), and so many other minor landforms occupying 5% area.

Landforms of denudational origin are formed where the denudation processes dominate over the other process. The mapped denudational landforms are low to moderately dissected hills and valleys, Pediment- Pediplain Complex.

The area is characterized by denudational originated pediplained topography represent flat or gently sloping to undulating rock floored erosion surface, typically developed by sub aerial agents at the base of receding residual hills, residual mounds and underlain by bare bedrock that are sometimes covered by scrub and bushes. At places it consists of discontinuous veneer of soil cover derived by the weathering of country rock with gentle undulated terrain with clusters of low to moderately dissected hills shows NW-SE & E-W trend situated on southern part of the study area. (Fig.2.2) These areas are occupied by litho units of Shale of Chitravati Group of Cuddapah Supergroup and Pink Granite, Grey Biotite Granite, Grey Hornblende Biotite Granite, Grey Hornblende Biotite Gneiss of PGC - II. It is characterized numerous joints and fractures.

Landform of structural origin is related to structural aspect of the area. Most of the landforms under this class have genesis related to underlying structure. Structural landforms identified in the study area are Low Dissected Hills and Valleys, Low Dissected Lower Plateau, Moderately Dissected Hills and Valleys. These hills have linear as well as arcuate pattern. Outcrops of Dolomite and Quartzite represent these hills, characterized by the presence of numerous joints blocks displaying varying degrees of angularity or roundness. (Fig.2.2) Anthropogentic activities like active mining, mine dumps and abandoned quarry are situated in central and NW part of the study area. (Fig.2.2)

Major water bodies are present easternly flowing Moganur Eru River in the northeastern part and its tributaries, numerous lakes, tanks and canals.

Fig.2.2 Geomorphology and Lineament map of the Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

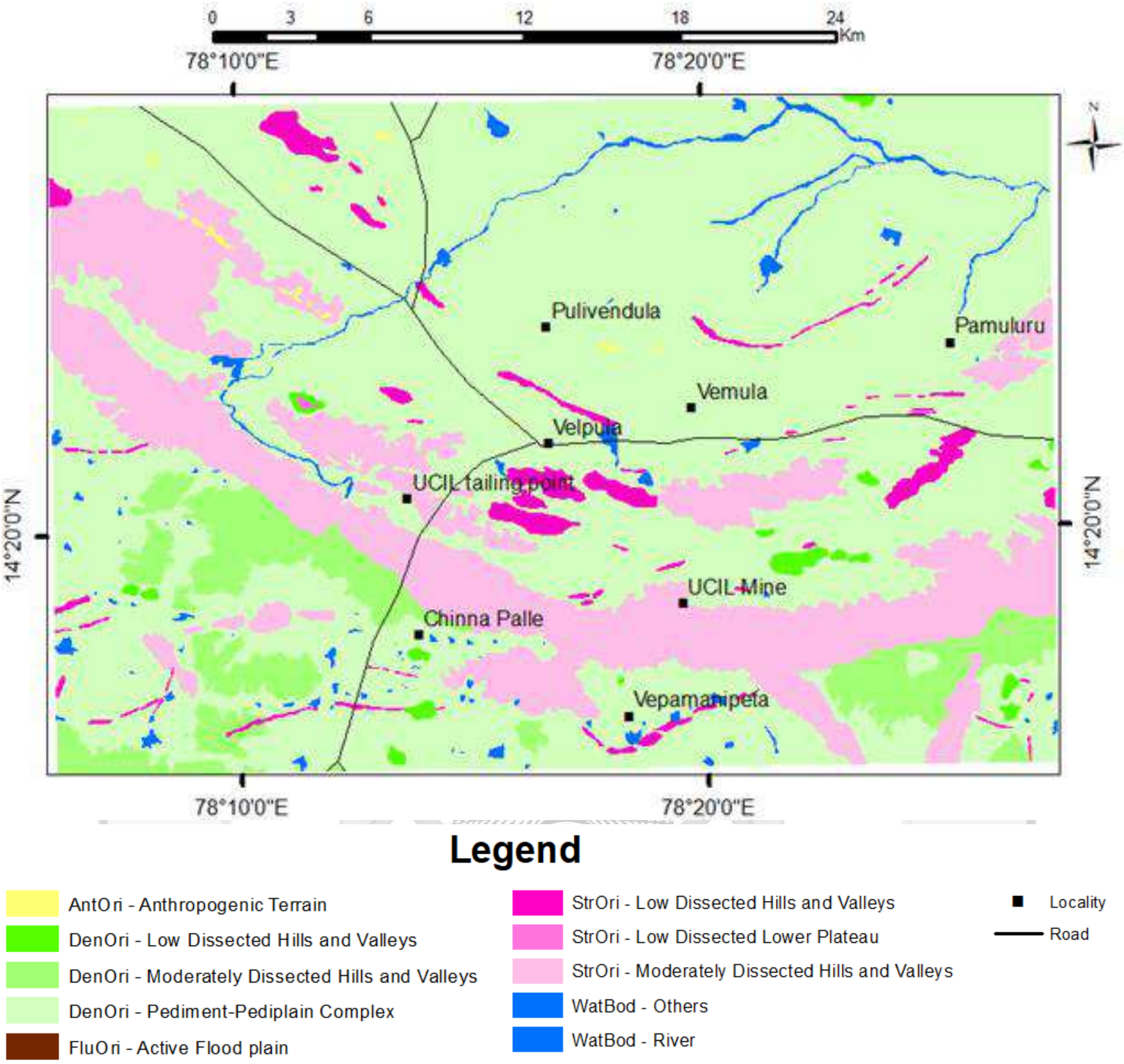


Fig. 2.3 Field photograph of pediplain area in the foreground and the dissected hill and valleys in the background near Kondareddipalle.

Fig. 2.4 Field photograph moderatly disecteed hill and residual hill with pediment zone, Batrepalli.

Fig. 2.5 Field photograph of pediplain area in the foreground and the linear Moderaly dissected hill and valleys in the background at Giddangivari palli.

Fig. 2.6 Field photograph of pediplain area in the foreground and the linear low dissected hill and valleys in the background at Kadri ghat road.

Fig. 2.7 Field photograph of chains of diseected hill in Background surrounded by pediment in Ambakapalli

Anthropogentic activities like active mining, mine, and abandoned quarry are situated in central and NW part of the study area in and around Hutti, Heera, Buddini and Ooti (Uti) areas (Fig.2.15 - 2.20)

Fig.2.8 Field photograph shows UCIL Tailing plant near Kanampalli

Fig.2.9 Satelliate image (google earth) shows Tailing pond and UCIL Plant Tummalapalli area, Pulivendula, Y.S.R Kadapa district, Andhra Pradesh.

2.3 LAND USE AND LAND COVER

Land cover is defined as the features that are present on the earth 's surface. Land use refers to the human induced changes for agricultural, industrial, residential or recreational purposes. LU/LC changes, whether of natural origin or man-made, can influence the local environment of the area (Ramachandra et al., 2012). The land use and land cover map were prepared using the Survey of India Open Series Map of the area as the base map and was updated with from the website https://livingatlas.arcgis.com/landcover. The land use and land cover in the area exhibit a variety of categories including wastelands, barren rock, riverbed cultivation, scrub-covered wasteland, stone waste, hill with scrub, water channel area, plantations, rivers, sandy areas, villages, Kharif and rabi crops, deciduous dense/closed forests, deciduous dense/open forests, open pit mining, underground mining, and habitation.

Shrubs and thorny bushes dominate a significant portion of the area. The southern and southeastern parts are occupied by Dorigallu and Gorivikanuma Reserve Forests. Around one-third of the land is used for cultivation, while the remaining portion is barren land. Water bodies such as canals, wells, and ponds are also present. Due to agricultural and industrial activities, some 1st and 2nd order streams near the villages have been converted into agricultural land. Agricultural practices have led to the narrowing down of stream widths, and sediments and slope wash have been contaminated by the use of fertilizers and pesticides. In the Vemula area, old working open pit mines of barytes can be observed, and the disposal of mine wastes and tailings has resulted in the rapid degradation of agricultural land.

The major sources of irrigation in the area are bore wells and dug wells, with rainfall during the monsoon season being crucial for cultivation. The main crops grown in the area include paddy, groundnut, cotton, chili, sweet lime, mango, sapota, sugarcane, banana, betel leaves, tomato, and brinjal. The cultivation of paddy and bajra is particularly intensive in the gently undulating plains with sparse natural vegetation. Chemical fertilizers commonly used in the area include ammonium sulfate, ammonium sulfate nitrate, mono-ammonium phosphate, calcium ammonium nitrate, urea, bone meal, and superphosphate of potash. The use of chemical fertilizers is more widespread in the mandals of Vempalle, Vemula, and Vepamanipeta.

Fig.2.10 Landuse and Landcover map of the Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

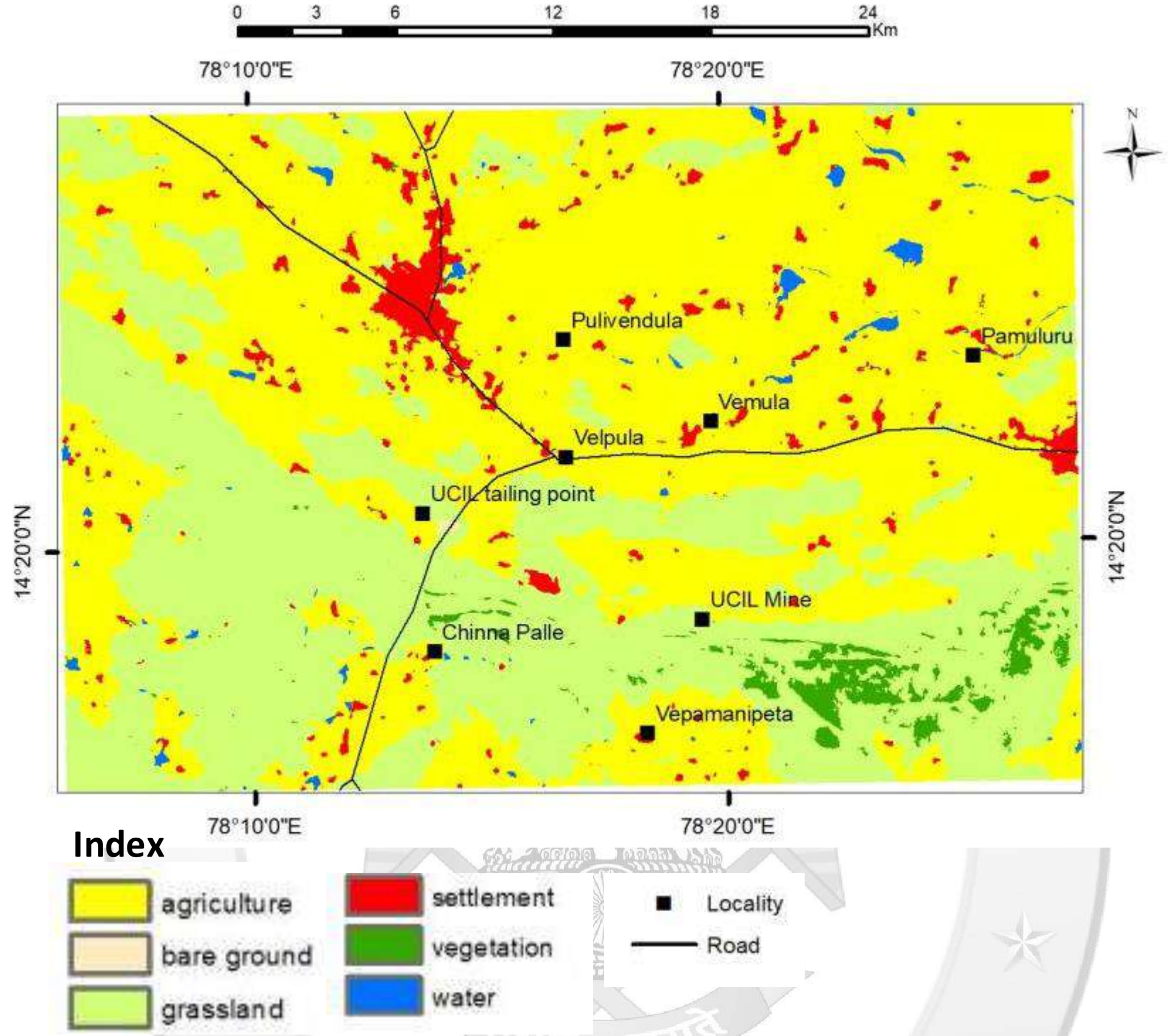


	
Fig.2.11 Field photograph showing Sunflower cropping in the Velpula.	Fig.2.12 Field photograph showing Citrus limetta planitation in Iptla.

	
Fig.2.13 Field photograph showing Cicer arietinum crop in Bakkanagaripalli	Fig.2.14 Field photograph showing groundnut crop in Kothapalle.
	
Fig.2.15 Field photograph showing flower planitation in the Tummalapalli area	Fig.2.16 Field photograph showing Sorghum farming in Vemula.
	
Fig.2.17 Field photograph showing cotton crop in Achavelli area.	Fig.2.18 Field photograph showing dragan fruit planitation in Achavelli area.

Fig.2.19 Field photograph showing Safflower (Carthamus tinctorius) crop near Nallacheruvu

Fig.2.20 Field photograph showing Safflower (Carthamus tinctorius) crop near Tummalapalli

Fig.2.21 Field photograph showing Forest area in Puntakonnama area

Fig.2.22 Field photograph showing Forest area in Ambakapalli area

Fig.2.23 Field photograph showing Forest area in Lakkasamudram

Fig.2.24 Field photograph showing manmade excavation in Boggudupalli.

CHAPTER-3

GEOLOGY AND STRUCTURE

3.0 REGIONAL GEOLOGY:

The Cuddapah Basin in Andhra Pradesh, located in the southeastern part of Peninsular India, is crescent-shaped and spans an area of 44,000 square kilometers. It is approximately 440 kilometers long and has a maximum width of 145 kilometers in the middle. The basin is characterized by Proterozoic sediments resting on an Archaean gneissic complex, which includes greenstone belts such as Kadiri, Veligallu, and Gadwal, indicating a significant nonconformity.

The lithostratigraphy of the Cuddapah Basin consists of four major groups from bottom to top: Papaghni, Chitravati, Nallamalai, and Kurnool groups. In the Pulivendula, Tummalapalle, and Brahmanapalle-Vemula areas, the Papaghni and Chitravati groups are exposed. The Tummalapalle uranium deposit is situated in the southwestern margin of the Kadapa Basin, and the uranium mineralization is hosted by the Vempalle carbonate rock Formation, which is part of the Papaghni group. The uranium ore zone contains minerals such as pitchblende, coffinite, and a U-Ti complex, with coffinite being fine-grained and associated with pyrite. Other minerals found in association with uranium include pyrite, chalcopyrite, molybdenite, and collophane.

Chrysotile asbestos is found in zones of serpentinization between dolomite sills and magnesian limestone, typically at the upper contact of the Vempalli Formation of the Papaghni group. This occurs along a 15-kilometer belt from Brahmanapalli to Lopatnutala in the Pulivendula Mandal.

Barytes (barium sulfate) is present in Vempalli dolomite and associated basic igneous rocks in Pulivendula, Kamalapuram, and Kadapa taluks. It occurs as veins, and disseminated pyrite, chalcopyrite, and malachite are commonly associated with barytes.

In the Indian context, certain trace elements including lead, mercury, chromium, cadmium, copper, aluminum, and uranium, as well as arsenic, are of major concern due to their potential health impacts. These elements have the ability to bioaccumulate in the human body and are excreted at a very slow rate, making them hazardous and potentially causing chronic degenerative diseases with prolonged exposure to contaminated environments.

Fig.3.0 Generalised geology map showing Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

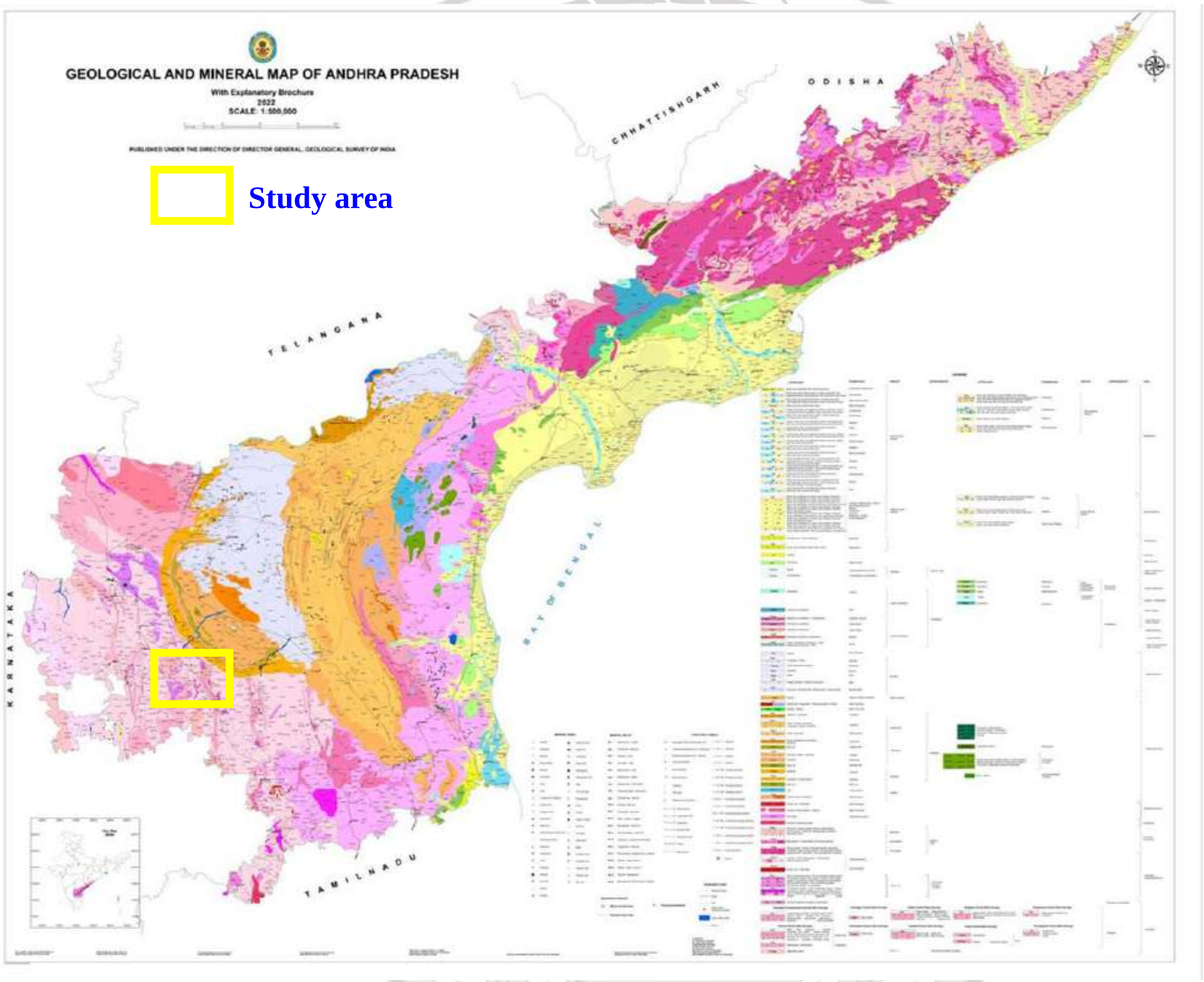


Fig.3.1 Geological map of the Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

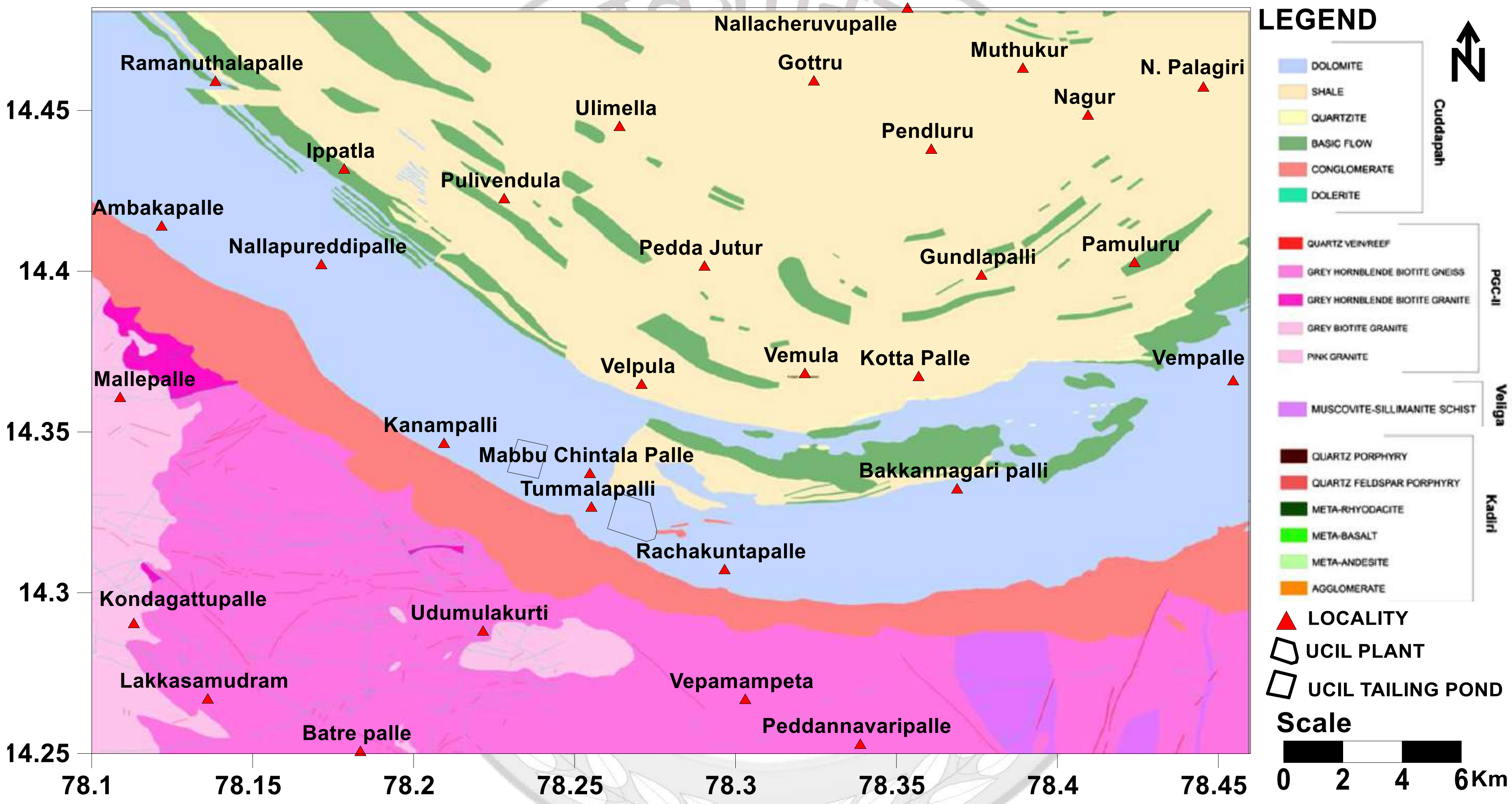
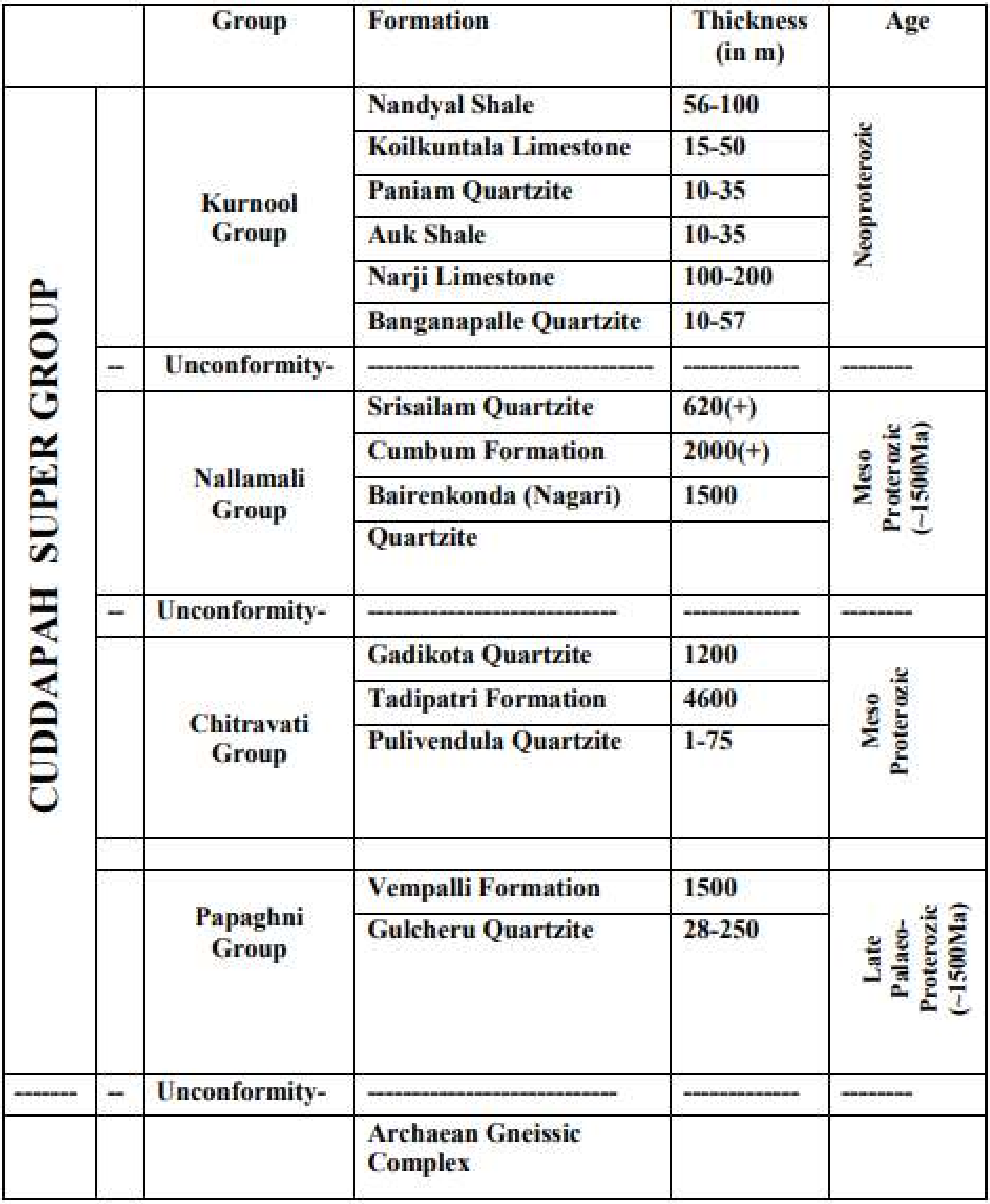


Table. -3.1: Generalized Stratigraphic succession of the Cuddapah Supergroup (after GSI, 1981)



		Group	Formation	Thickness (in m)	Age
CUDDAPAH SUPER GROUP		Kurnool Group	Nandyal Shale	56-100	Neoproterozic
			Koilkuntala Limestone	15-50	
			Paniam Quartzite	10-35	
			Auk Shale	10-35	
			Narji Limestone	100-200	
			Banganapalle Quartzite	10-57	
	--	Unconformity-	-------------------------------	-------------	--------
		Nallamali Group	Srisailam Quartzite	620(+)	Meso Proterozic (~1500Ma)
			Cumbum Formation	2000(+)	
			Bairenkonda (Nagari)	1500	
			Quartzite		
	--	Unconformity-	---------------------------	-------------	--------
		Chitravati Group	Gadikota Quartzite	1200	Meso Proterozic
			Tadipatri Formation	4600	
			Pulivendula Quartzite	1-75	
		Papaghni Group	Vempalli Formation	1500	Late Palaeo-Proterozic (~1500Ma)
			Gulcheru Quartzite	28-250	
-------	--	Unconformity-	---------------------------	-------------	--------
			Archaean Gneissic Complex		

3.1 GEOLOGY OF THE STUDY AREA

The study area is covered by the Papaghni and Chitravati Groups of Cuddapah Supergroup, which rest unconformably over the PGC and Dharwars. The older metamorphics, which mainly include amphibolites, biotite schist, meta gabbro, sillimanite chlorite schist and pyroxenite and they occur as xenoliths of varying dimensions within the major Peninsular gneissic complex, further the amphibolites and biotite schist occur as a zone of enclaves in the migmatite of the Peninsular gneissic complex. The Veligallu schist belt rocks comprise of small bands of quartz-muscovite-sillimanite schist. It occurs as small rafts within the grey hornblende-biotitegranite gneiss and pink granite rocks of PGC which are in turn intruded by thin quartz veins and dolerite dykes.

3.1.1 PENINSULAR GNEISSIC COMPLEX (PGC-II):

The Peninsular Gneissic Complex (PGC-II) in the study area primarily consists of grey hornblende granite gneiss and pink granite. These rock types are predominantly exposed in the western part of the Veligallu schist belt and within the core of the antiformal schist belt. The granite gneiss is widely exposed in the southern part of the study area, forming prominent hills, hillocks, knolls, and monadnocks. It exhibits a wide range of compositions, varying from granite to granodiorite, diorite, and quartz diorite. In the southern part of the area, localized patches of pink granite can be observed within the major Peninsular Gneissic Complex. These pink granites intrude into the grey hornblende granites and gneiss. They are characterized by a massive structure, medium-grained texture, and consist primarily of pink feldspars, quartz, and epidote as the main constituents. Biotite is present as an accessory mineral within the pink granites (Fig. 3.2-3.9).

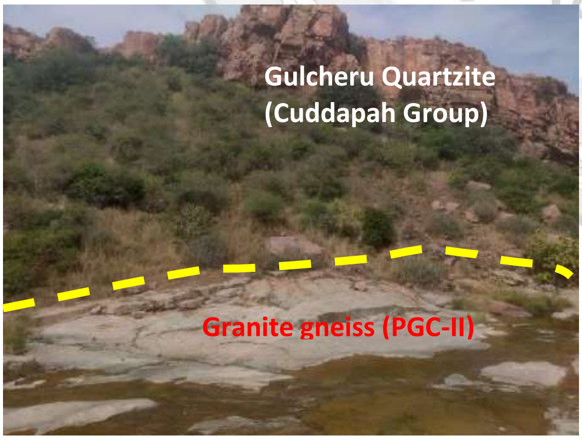


Fig.3.2 Field photograph showing contact between Gulcheru quartzite and Granite gneiss at Namalagundu.

Fig.3.3 Field photograph of hornblende biotite granite gneiss showing alternative quartz-feldspar rich bands and mafic bands showing gneissosity

Fig.3.4 Field photograph of hornblende biotite granite gneiss showing Micro mafic enclave (MME)

Fig.3.5 Field photograph of hornblende biotite granite gneiss showing later pegmatite intrusion

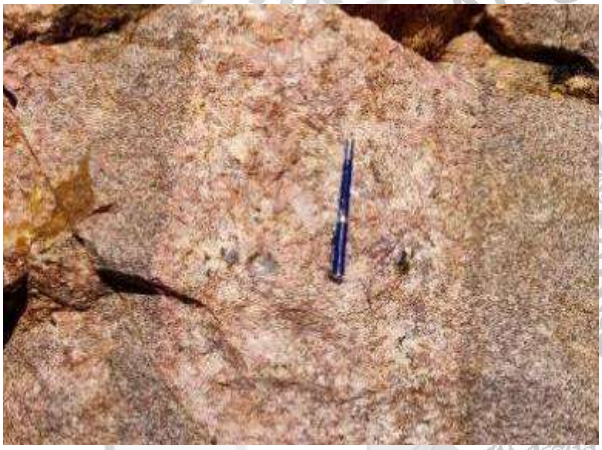


Fig. 3.6 Field photograph of pegmatite vein in pink granite.

Fig.3.7. Hand specimen of Grey granite shows plagioclase, quartz and biotite.

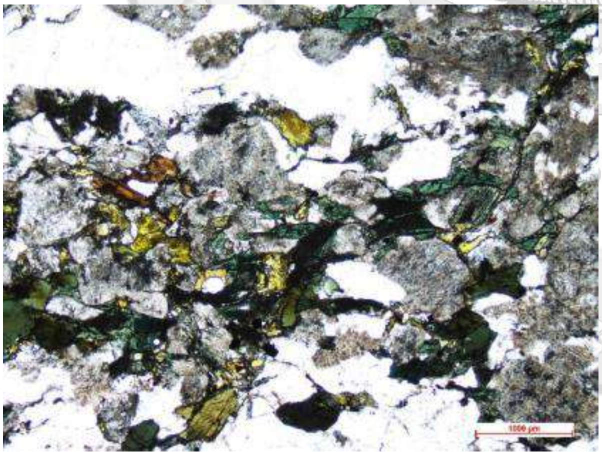


Fig.3.8 Photomicrograph of hornblende biotite granite gneiss (PS-19) showing alternative quartz feldspar bands and mafic rich bands showing crude gneissosity, XPL.

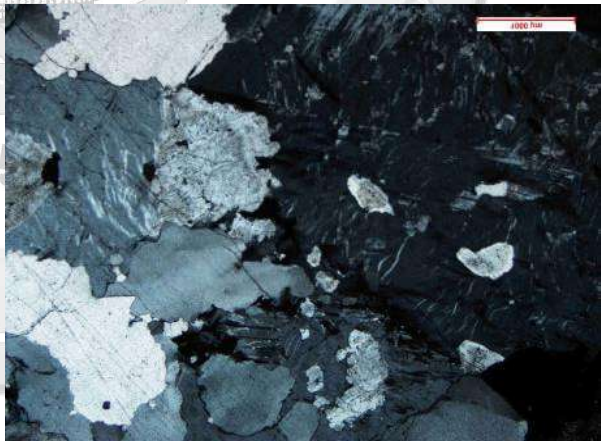


Fig.3.9 Photomicrograph of pink granite showing quartz and feldspar, XPL.

3.1.2 CUDDAPAH SUPERGROUP:

The Cuddapah Basin is characterized by a significant unconformity on basement granite, which surrounds the eastern greenstone belt of Veligallu. The basin is marked by cycles of quartzite and carbonate shale. Early sediments in the basin are interbedded with basic volcanic sills. In the southwestern part of the Cuddapah Basin, two distinct rock types are present. The lower unit is known as Gulcheru quartzite and is composed of arenaceous (sandy) rocks. The upper unit is called Vempalle Formation and consists of calcareous (limestone) rocks. In the central part of the basin, there is an alternating sequence of arenaceous (sandy) and argillaceous (clayey) rocks. The arenaceous unit is referred to as Pulivendula quartzite, while the argillaceous unit is known as Tadpatri shale. The study area within the basin is renowned for its mineral potential. It is known to contain deposits of limestone/dolomites, bedded and vein barytes, asbestos, and steatites. Additionally, there are occurrences of base metals, uranium, and abundant building and ornamental stones.

PAPAGHNI GROUP:

In the study area, the Papaghni Group, which is part of the lower Cuddapah Supergroup, includes the Gulcheru and Vempalle Formations. These formations are well exposed in the southeastern and central parts of the area and are primarily found in low-lying dissected plateaus, with layers that are sub-horizontal in disposition. The Palaeo-Proterozoic Papaghni Group forms an arcuate outcrop belt in the southwestern Cuddapah Basin. Interestingly, this outcrop belt does not exhibit a clear relationship with the tectonic grain of the underlying basement lithology. The facies observed in the Gulcheru Quartzite are interpreted as initial alluvial fans that later transitioned into a shallow-marine coastline and shelf environment. This transition occurred during a period of transgression under overall thermal subsidence, which could be associated with post-plume thermal relaxation processes. This information was noted by V. Balasubramanian and S. V. Raghupathi Rao in 1986.

GULCHERU FORMATION:

The Gulcheru quartzite, with a thickness ranging from 30 to 200 meters, is found unconformably overlying the Peninsular Gneissic Complex and Veligallu schist belt. In the southern part of the region, the contact between the crystalline rocks and the Papaghni sediments is marked by intermittent and discontinuous layers of oligomictic conglomerate, particularly observed in the Kadiri-Pulivendla section. These conglomerate layers consist of a mixture of conglomerate, grit, sandstone, quartzite, and shale bands, which are intercalated within the Gulcheru quartzite. The basal conglomerate is characterized by its coarse texture, ranging from brown to reddish brown in color, and it contains a high iron content. The conglomerate is polymictic in nature, consisting of pebbles and cobbles predominantly composed of vein quartz, jasper, and variegated chert. These conglomerate beds are highly resistant and give rise to cliffs and hogbacks due to their hard and durable nature. The Gulcheru Formation primarily consists of quartzite, which can exhibit white, buff, and brown colors. The quartzite is hard, compact, and has a fine to medium grain texture. Thin shaley horizons can also be observed within the formation. In some areas, the quartzite may have a cherty variety. Additionally, intra-formational conglomerates can be seen in the Namalagundu-Pulivendula road section. Localized features such as ripple marks and current.

	
Fig.3.10 Field photograph of Gulcheru quartzite showing crossbedding (Cuddapah Group) at Namalagundu.	Fig.3.11 Hand specimen quartzite Showing massive nature.

VEMPALLE FORMATION:

The Vempalle Formation has an approximate thickness of 1900 meters and is primarily composed of stromatolitic dolomite, chert, and a thin unit (~100 meters) of sandstone and quartzite at the base. The formation is characterized by conical rounded hills that have a distinctive stepped appearance, and some beds within the formation exhibit cliff faces. The volcanic sills/flows are also present in the Vempalle strata, with amygdales occurring at the upper surface of the flows, often filled with minerals such as epidote, calcite, and zeolite (south-east of Bechayagaripalle). Algal/stromatolitic structures, including stratifera and callenia, can be observed within the dolomite of the Vempalle Formation. Chert bands are associated with the dolomitic limestone along their bedding planes and are easily noticeable due to weathering (Fig.3.12-3.29). The Vempalle Formation is well-known for its mineral potential, including occurrences of limestone/dolomites, bedded and vein barytes, asbestos, steatites, base metals, uranium, and abundant building and ornamental stones. In the barren mounds located south-east of Vemula and south of Bechayagaripalle, some old and new barytes workings have been observed. The country rock in this area is dolomite, exposed along the flanks of the hills and capped by quartzites. A narrow band of fine-grained basic rock, traversed by veins of silica and barytes up to 2 inches thick, intrudes the dolomite. Along the Pulivendula-Vempalle highway, old workings of asbestos mines can also be found. The trend of the Vempalle Formation is almost parallel to that of the underlying Gulcheru quartzite, with dips ranging from 10° to 30° to the north.

	
Fig.3.12 Field photograph of Dolomite showing layering, Tummalapalli.	Fig.3.13 Field photograph of Dolomite showing typical elephant skin wreathing.
	
Fig.3.14 Field photograph of Dolomite showing concentric growth of stromotolites, Ramanthapalle.	Fig.3.15 Field photograph of Dolomite showing Flow banding, Mabbuchintalapalli

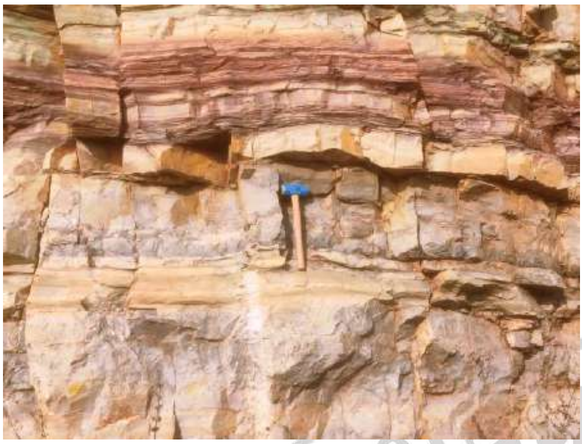


Fig.3.16 Field photograph of Dolomite and shale sowing alternative layering, Ambakapalli.

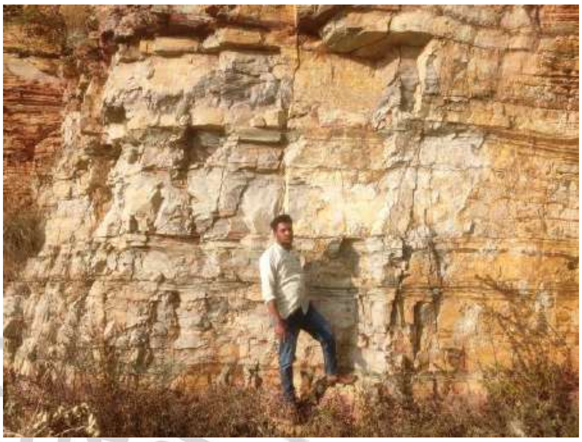


Fig.3.17 Field photograph of Dolomite and shale sowing alternative layering, Nalupureddy palli.

Fig.3.18 Field photograph of Dolomite showing concentric growth of stromotolites, Gunakalapalli.

Fig.3.19 Field photograph of Dolomite showing concentric growth of stromotolites, Chinnakudala.

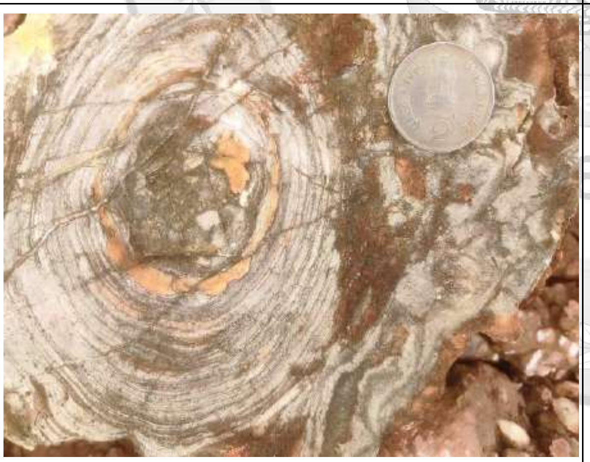


Fig.3.20 Field photograph of Dolomite showing concentric growth of stromotolites, Gunakalapalli.

Fig.3.21 Field photograph of purpule shale showing micro faults near UCIL tailing pond, Pulivendula-Kadiri old Ghat road.

Fig.3.22 Field photograph of purpule shale and dolomite showing dextral shear sence near Rachakuntapalli.

Fig.3.23 Field photograph showing alternative layers of purple and red shale , near UCIL Plant.

Fig: 3.24. Field photograph showing alternative layers of Shale and Dolomite , near Kanampalli

Fig: 3.25. Field photograph showing alternative layers of Shale and Dolomite , near Lingala road.

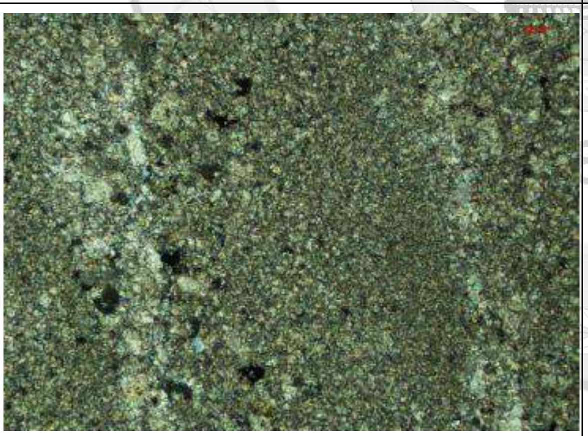


Fig.3.26 Photomicrograph of Cherty dolomite near Bhumayagaripalli ,XPL

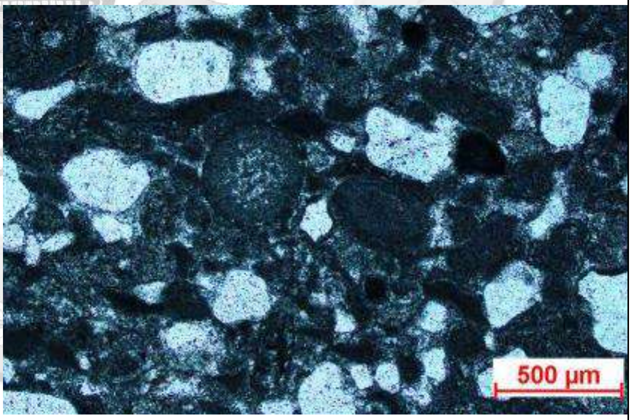


Fig.3.27 Photomicrograph of Dolomite near Tummalapalli ,XPL

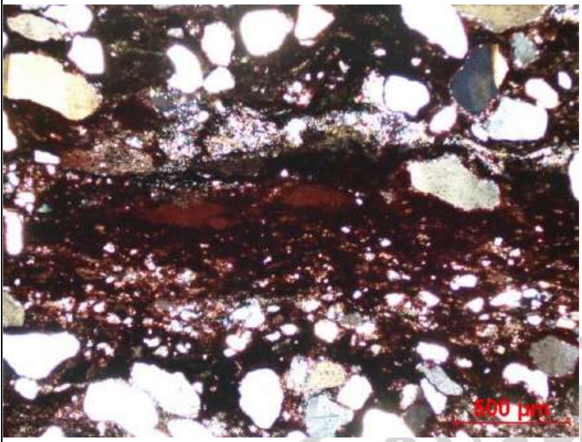
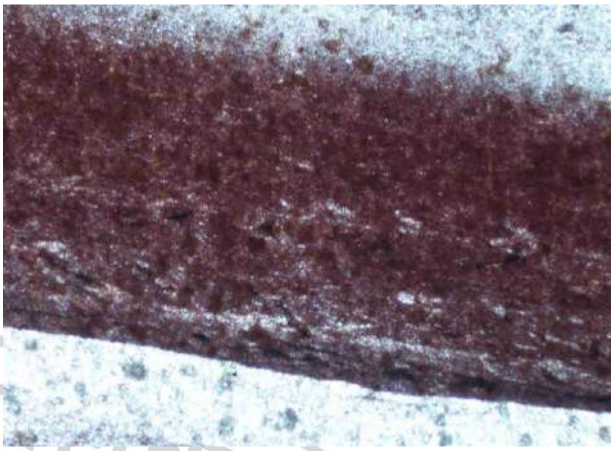
	

Fig.3.28 Photomicrograph of Shale near Kanampalli ,XPL	Fig.3.29 Photomicrograph of Dolomite near Tummalapalli ,XPL

CHITRAVATI GROUP:

The Group that disconformably overlies the Papaghni Group is composed of the lower Pulivendula quartzite and the upper Tadpatri Formation. The Pulivendula quartzite is predominantly comprised of basal conglomerate and quartzite, which are exposed in the southern and central parts of the studied area. The basal conglomerate is characterized by a brownish to purplish color and has a splintery texture. In the northern part of the area, the plain country is underlain by brownish to purplish colored splintery shale, which belongs to the Tadpatri Formation. This shale is a part of the upper portion of the Group and extends over a large extent in the northern region.

PULIVENDULA QUARTZITE:

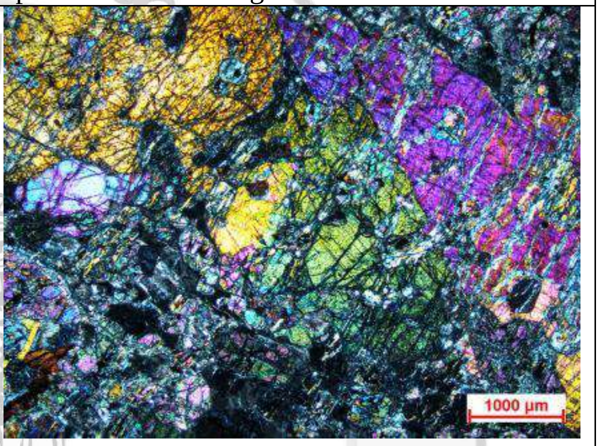
The Pulivendula Quartzite is primarily ferruginous in nature and stretches from Lingala in the northwest to Velamvaripalle in the southeast. It exhibits a general strike direction of WNW-ESE, which nears east-west orientation and then changes to NE-SW. The dips of the quartzite formation vary from 15° to 35°, with the dips trending towards NE east and NW. This formation is characterized by a basal conglomerate that overlies the Vempalle Formation, indicating the contact between the two formations. Additionally, there is a top conglomerate horizon within the Pulivendula Quartzite, marking its contact with the overlying Tadpatri Formation. South of Ammayyagaripalli, the top conglomerate horizon is clearly visible. It consists of pebbles ranging in size from 0.5 to 10 cm, including varieties such as white quartz, jasper, black chert, white banded chert, quartzite, and dolomite.

TADPATRI FORMATION:

Shale & tuff are main rock type in this Formation. The shale is purple to buff coloured soft, friable and associated with basic sills and flows. It maintains parallelism with the underlying PulivendulaFormation and shows gentle northerly and north-westerly dips of 10° to 30°. The Pulivendula quartzite with conglomerates occurs as narrow bands within the Tadipatri formations. Because of the hard and resistant nature of the rocks, these beds form cliffs or steep slopes. A number of sills and dykes of doleritic to basaltic composition are exposed near Chegaleru, Alavapadu, Moilacheruvu, Busireddipalle and Virapunayanipalle occur in the shale (Fig. 3.21-3.29).

BASIC INTRUSIVE:

The Vempalle and Tadpatri Formations in the area have experienced significant igneous activity, with the intrusion of a suite of volcanic igneous rocks. This volcanic activity likely occurred shortly after the deposition of the Papaghni and Chitravati Groups. The presence of numerous basic sills and flows within the Vempalle and Tadpatri Formations indicates this igneous activity. The sills are observed as prominent dark low ridges, varying in size from a few feet to several hundred feet in length and width. In their westerly extensions between Tallapalle and Tallapalle-Velamvaripalle, they can reach a maximum width of about 4 km. Amygdales, which are small vesicles or cavities in the rocks, can be found at the upper surfaces of the volcanic flows. These amygdales are typically filled with minerals such as epidote, calcite, and zeolite, particularly in the southeast of Bechayyagaripalle and to the south of Tallapalle and Bechayyagaripalle (Fig.3.30-3.33). The volcanic rocks in the region, which are fine-grained and basaltic in composition, consist of multiple flows, some of which exhibit high degrees of epidotization and vesicular texture. The vesicles or cavities within these rocks are filled with minerals like epidote, quartz, and calcite. In the regions around Vemula, south of Bechayyagaripalle, Velpula, Vempalle, and Pulivendula, these intrusive volcanic rocks have played a role in the formation of valuable mineral deposits, including asbestos, barytes, and steatite.

	
Fig: 3.30. Field photograph showing basic rock in Tallapalli.	Fig: 3.31. Field photograph showing stypical spheroidal weathering.
	
Fig: 3.32. Field photograph showing Vesicles in basic rock (Near Bechchayyagpalli.	Fig.3.33 Photomicrograph of basic rock near Velpula ,XPL

3.1.3 VELIGALLU SCHIST BELT:

The Veligallu schist belt, located in the middle southern part of the study area, exhibits an antiformal structure with a northward plunge. It is influenced by several fault systems trending N-S, NW-SW, and NE-SW, while joints and fractures commonly trend NNW-SSE and E-W. The metavolcanic member, along with the banded iron formation, shows a near N-S foliation trend with steep dips to the east and west. The schist belt has undergone three phases of folding and is accompanied by greenschist to lower amphibolite facies of metamorphism. The first phase of folding resulted in tight isoclinal folds, giving rise to regional N-S schistosity. The Gulcheru quartzite is observed overlying the Veligallu schistose members.

3.2 STRUCTURE: The Papaghni and Chitravati Group of rocks exhibit horizontal to sub-horizontal bedding, with varying trends from NE-SE to WNW-ESE, near E-W, and swinging to NE-SW. The beds generally have gentle dips of 5° to 10° to the north. The rocks of the

Papaghni Group show south-easterly dips in the north, becoming easterly in the middle portion, and gradually changing to north-easterly direction in the south, indicating a dip towards the center of the basin. The primary sedimentary structures associated with the stromatolites in the Papaghni and Chitravati Group indicate an intertidal (littoral) sand flat and mud flat environment. Other sedimentary structures observed in the elastic members of the formation include herringbone, cross bedding ripple marks, mud cracks, and flat pebble conglomerates. Ripple marks, particularly transverse oscillatory and interference ripples, are seen in the quartzite intercalations of the Vempalle Formation. Polygonal mud cracks filled with sandy material are common in the mudstones and shale of the formation.

3.3 MINERALISATION:

The study area exhibits a diverse range of mineral potential. Some of the prominent mineral resources include: Limestone/Dolomites: The area is known for the occurrence of limestone and dolomite deposits. These carbonate rocks have significant economic importance and can be utilized in various industries, including construction, cement production, and as a raw material for lime production. Bedded & Vein Barytes: Barytes, also known as barite, is a mineral commonly used in drilling muds in the oil and gas industry. The region shows both bedded and vein-type barytes deposits, indicating potential for extraction and commercial utilization. Barytes mineralization is mainly associated with E-W trending faults and to a lesser extent with accompanying shears. The mineralization is epigenetic in origin and postdates the Chitravati Group in terms of age. Shearing and brecciation of the intrusive rocks, marked by epidotization and solidifications, are more commonly observed near faults. Asbestos: The presence of asbestos deposits has been observed in the area, particularly along the upper contacts of basic flows/sills and the Vempalle formation. Asbestos is a fibrous mineral used in various applications, such as insulation and fireproofing. Steatites (Soapstone): Soapstone, also known as steatite, is a metamorphic rock with high talc content. It is often used in the manufacturing of ceramics, countertops, and carvings due to its softness and heat resistance. Steatite deposits have been identified south and southeast of Lingala along the upper contact of flows and dolomite. Base Metals: The presence of disseminations of galena (lead sulfide), pyrite, chalcopyrite (copper iron sulfide), bornite (copper ore), malachite, and azurite (both copper carbonate minerals) indicates potential for base metal mineralization in the area. Uranium: Uranium, a radioactive element used in nuclear power generation, has been mentioned as a potential occurrence in the region. Further exploration and assessment would be necessary to determine its economic viability.

Building and Ornamental Stones: The study area also possesses abundant resources of building and ornamental stones. These stones, which may include granite, gneiss, and other suitable rock types, can be utilized in construction, architecture, and decorative applications. Silica and Barytes Veins: Veins of silica and barytes ranging up to 2 inches in thickness traverse the dolomite exposed along the flanks of hills and are capped by quartzites. These veins represent potential mineral resources for silica and barytes extraction. It's important to note that further exploration, evaluation, and feasibility studies would be required to assess the quantity, quality, and economic viability of these mineral resources in the study area.

Table 3.2 Petrographic sections collected from the study area

Sl No	Longitude	Latitude	Sample No	Rock type	Location
1	78.2594	14.3261	PS-1/22-23	Dolomite	Tummalapalli
2	78.3156	14.3348	PS-2/22-23	Dolomite	Bhumayagaripalli
3	78.2106	14.3603	PS-3/22-23	Dolomite	NW of Kanampalli
4	78.3013	14.3121	PS-4/22-23	shale	Rachakuntapalle
5	78.3083	14.3528	PS-5/22-23	Basic Rock	Bechchayyagpalli
6	78.1223	14.4488	PS-6/22-23	Stromotolitic dolomite	Gunakalapalli
7	78.3605	14.3104	PS-7/22-23	shale	Giddangivaripalli
8	78.2346	14.3570	PS-8/22-23	oxidised ore	K Kothala
9	78.2083	14.3485	PS-9/22-23	shale	Kanampalli
10	78.1312	14.4307	PS-10/22-23	shale	Ambakapalli
11	78.4374	14.2693	PS-11/22-23	HBL+ BT gneiss	Siddreddypalli
12	78.4527	14.2749	PS-12/22-23	Muscovite Schist	Siddreddypalli
13	78.1999	14.3357	PS-13/22-23	Quartzite	Namalagundu
14	78.3855	14.4810	PS-14/22-23	shale	Moilalacheruvu
15	78.1999	14.3357	PS-15/22-23	HBL+ BT gneiss	Namalagundu
16	78.2146	14.3461	PS-16/22-23	Shale/ Dolomite	Kanampalli tank
17	78.2882	14.3128	PS-17/22-23	shale	Tummalapalli
18	78.1155	14.3804	PS-18/22-23	HBL Granite	Basireddy palli
19	78.1085	14.2755	PS-19/22-23	HBL+ BT gneiss	Reddygaripalli
20	78.3153	14.2670	PS-20/22-23	HBL+ BT gneiss	Gunduvaripalli
21	78.15481	14.25583	PS-21/22-23	Pegmatite	Lakkasamudram
22	78.22691	14.32998	PS-22/22-23	Quartzite	Kadiri ghat road
23	78.1198	14.3389	PS-2322-23	Granite	Tappetivaripalli
24	78.1622	14.2546	PS-2422-23	Grey Granite	West of Battrepalli
25	78.2247	14.3087	PS-2522-23	Gneiss	Kadiri ghat road
26	78.2907	14.3753	PS-2622-23	Basic Rock	Velpula
27	78.3723	14.3520	PS-2722-23	Basic Rock	Velpula
28	78.1622	14.4348	PS-28/22-23	Asbestos	Ippatla
29	78.1465	14.4020	PS-29/22-23	Shale	Nallagondlavaripalli
30	78.2146	14.3461	PS-30/22-23	Dolomite	Kanampalli

CHAPTER-4

SEM STUDIES FOR IDENTIFICATION OF URANIUM BEARING MINERALS

4.1 SCANNING ELECTRON MICROSCOPE (SEM):

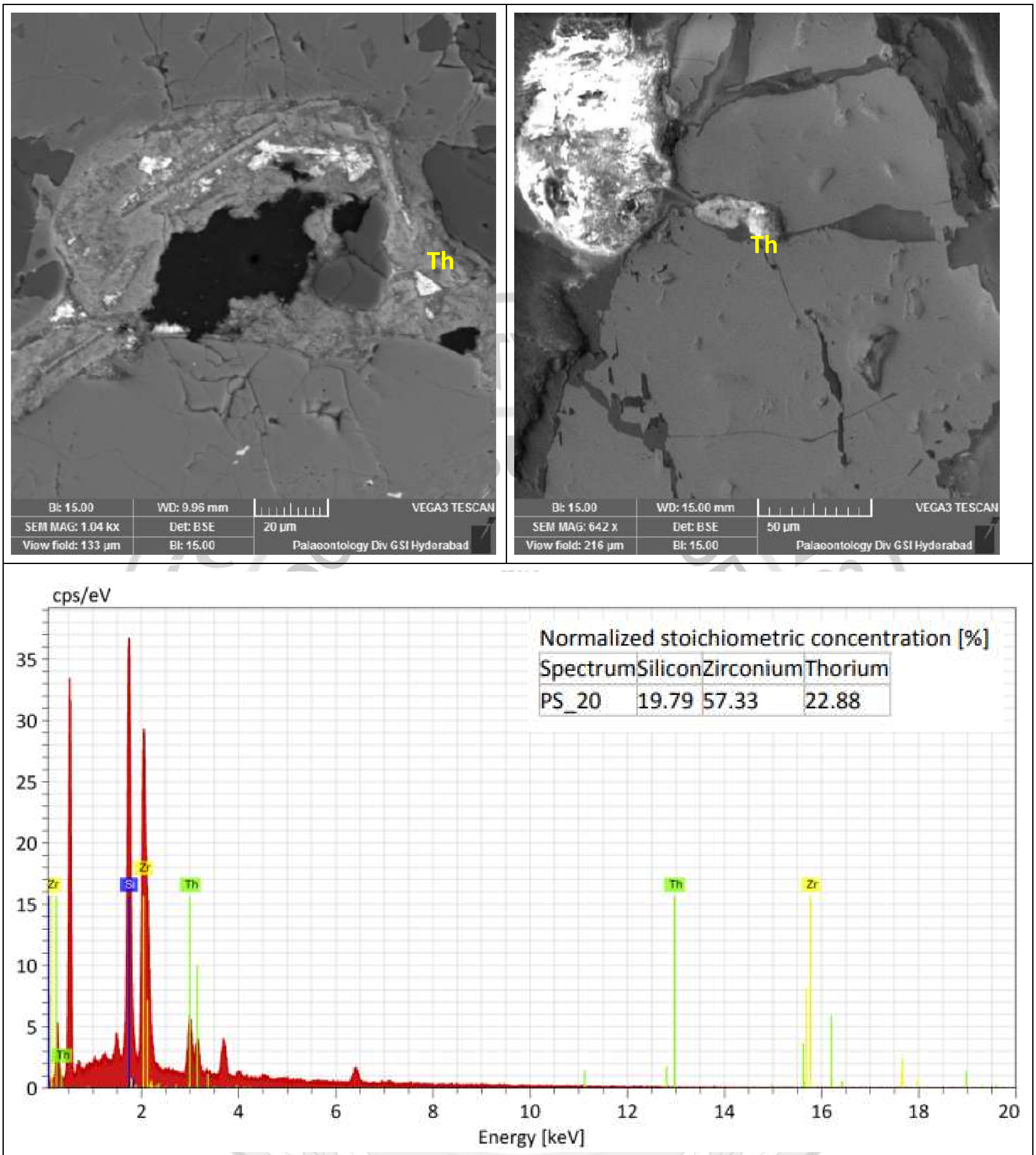
The SEM attached with EDS analyser was used during present study to know the mineral characterisation. The semi quantitative analysis was performed using TESCAN make VEGA3 LMU LaB6, EDX Bruker machine installed in Paleontology Division, Geological Survey of India, Southern Region, Hyderabad. The analysis helped to know experimentally the different mineral phases present in samples. A total of 10 thin-polished sections were selected for SEM studies. , enabling a comprehensive understanding of the mineralogical characteristics of the materials under investigation.

Grey Hornblende biotite gneiss, grey hornblende granite, pink granite are the dominant litho unit in Peninsular Gneissic Complex– group II. In the Grey Hornblende biotite gneiss (PS-20) and (PS-11), the main Titanium mineral associated with thorium phases identified grains size varies from 10 microns.

Gneiss (PS-25), Thorium associated with iron oxides grains size varies from 20 -30 microns.Muscovite schist (PS-12) uranium, thorium and REE mineral phases are identified grains size varies from 50-80 microns.

In shale , (PS-7, PS-8 & PS-9) uranium, thorium and fluorine mineral phases are identified with iron oxides. (Fig.4.1-4.8).

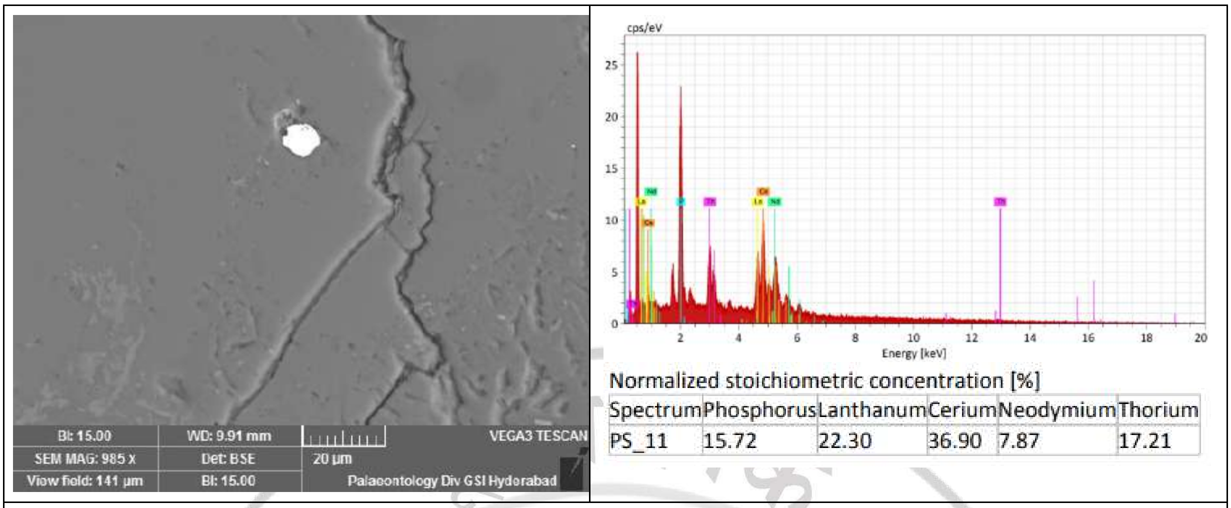
Dominant minerals of the area have been identified as Barite, Magnetite, Galena, Zircon, Allanite. Thorium is found in places. When Th-232 absorbs a neutron, it becomes Th-233, which eventually decays into protactinium-233 (Pa-233) and then further into uranium-233 (U-233).



Normalized stoichiometric concentration [%]

Spectrum	Silicon	Zirconium	Thorium
PS_20	19.79	57.33	22.88

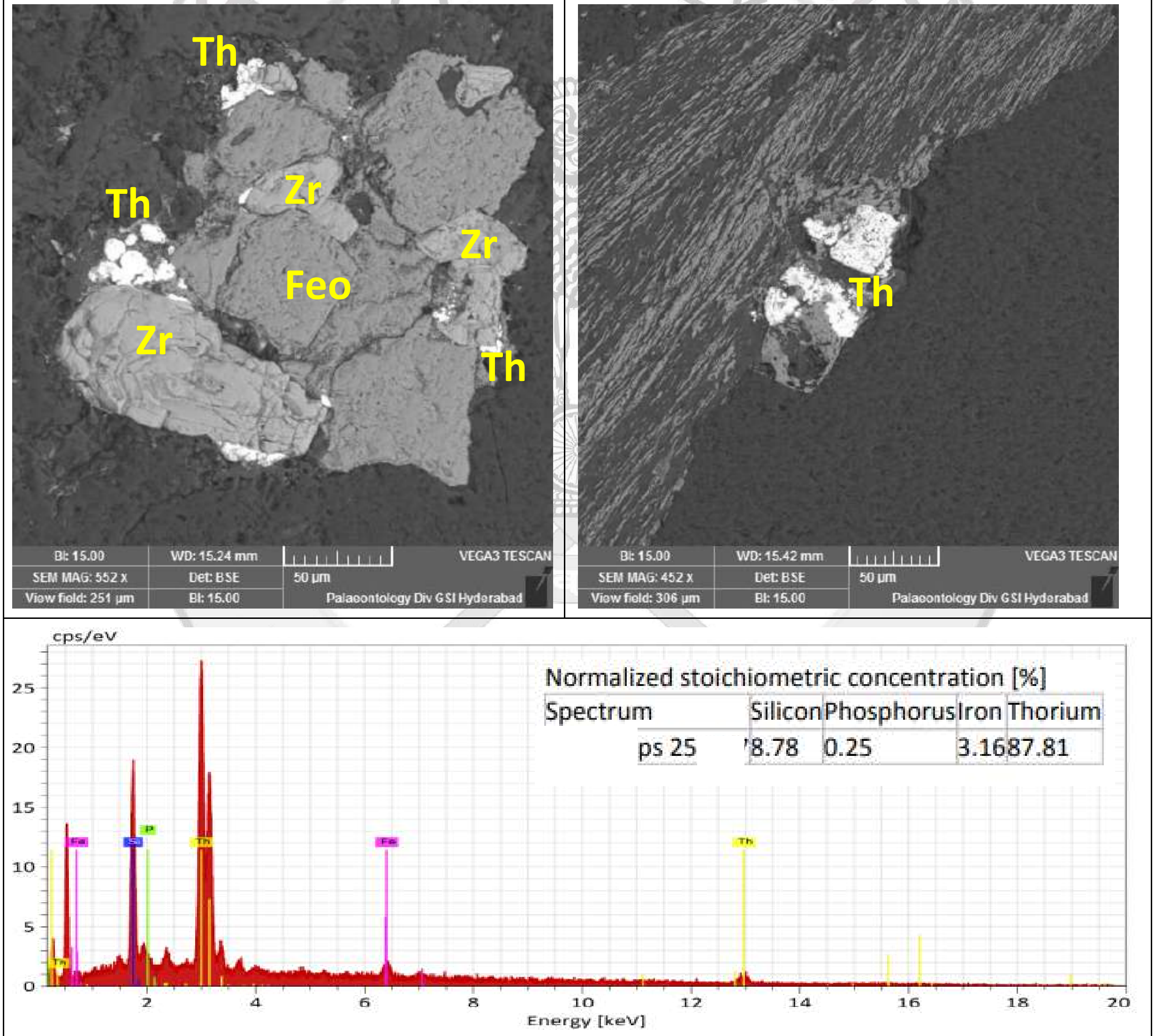
Fig. 4.1 BSE image and diffractogram showing Thorium (Th) in Hornblende Biotite Gneiss (PS-20), Gunduvaripalli



Normalized stoichiometric concentration [%]

Spectrum	Phosphorus	Lanthanum	Cerium	Neodymium	Thorium
PS_11	15.72	22.30	36.90	7.87	17.21

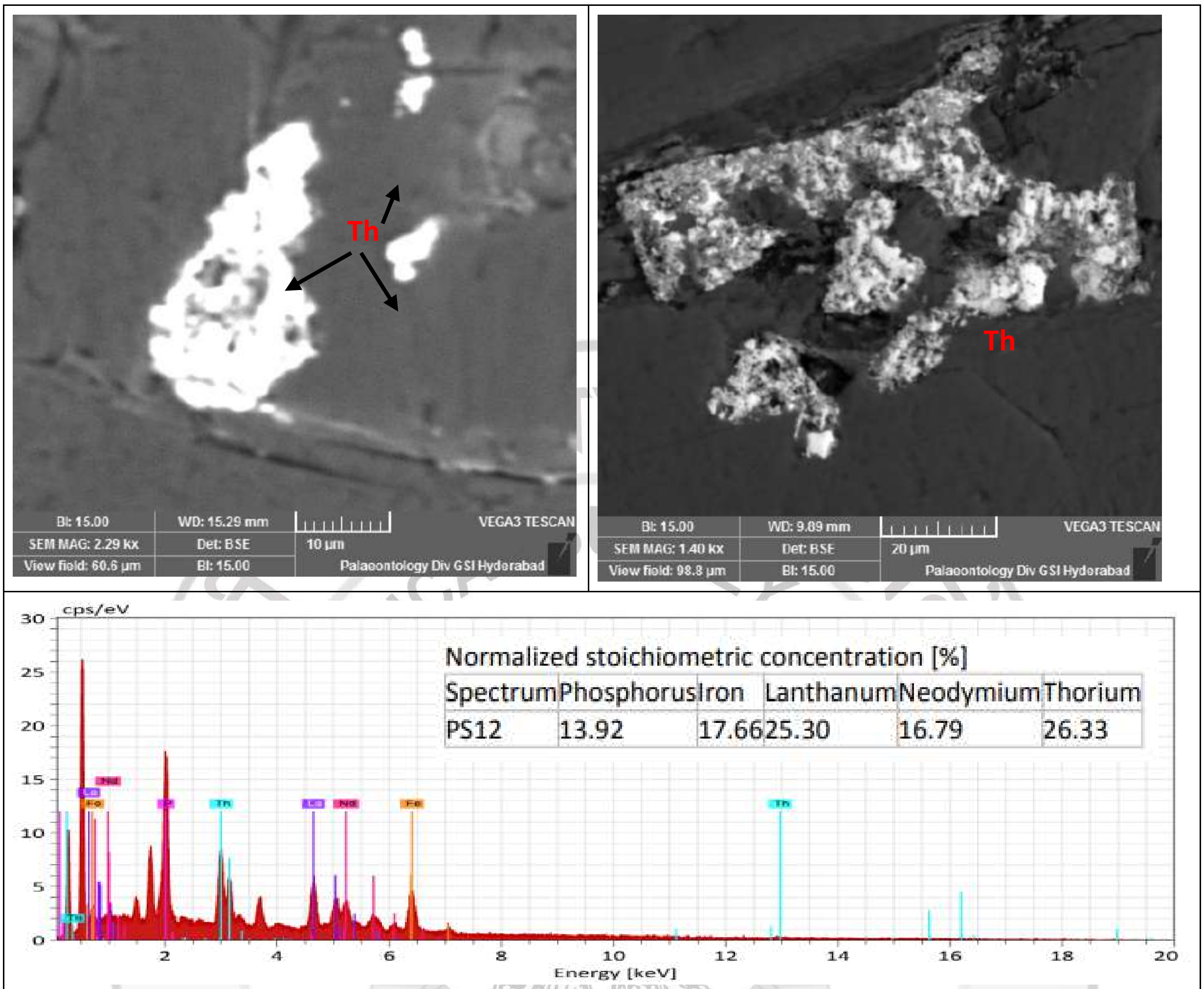
Fig. 4.2 BSE image and diffractogram showing Thorium (Th) in Hornblende Biotite Gneiss (PS-11), Gunduvaripalli



Normalized stoichiometric concentration [%]

Spectrum	Silicon	Phosphorus	Iron	Thorium
ps 25	'8.78	0.25	3.16	87.81

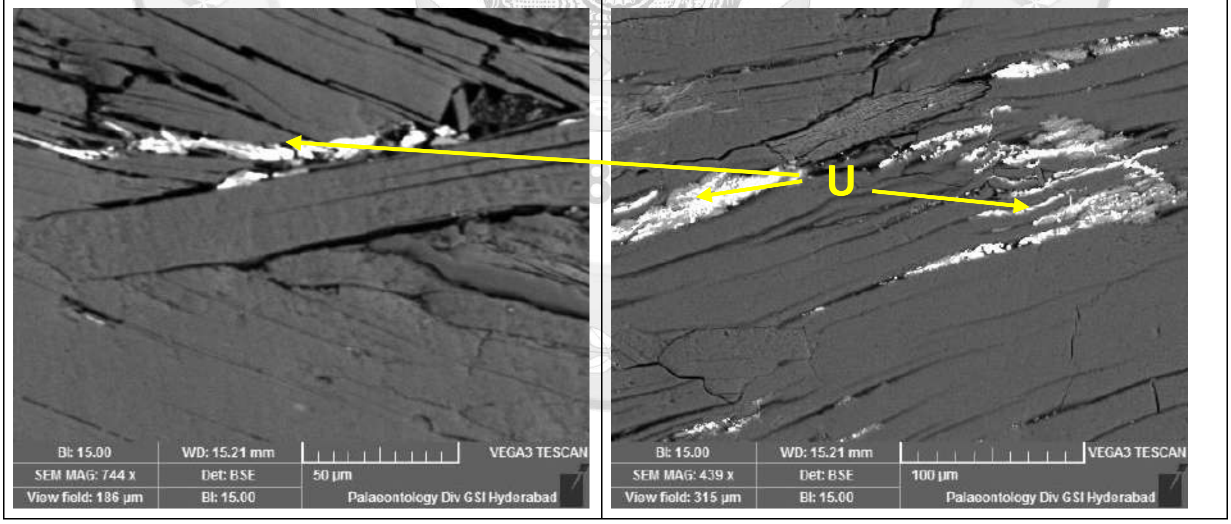
Fig. 4.3 BSE image and diffractogram showing Thorium (Th) in Gneiss (PS-25). Khadiri ghat road

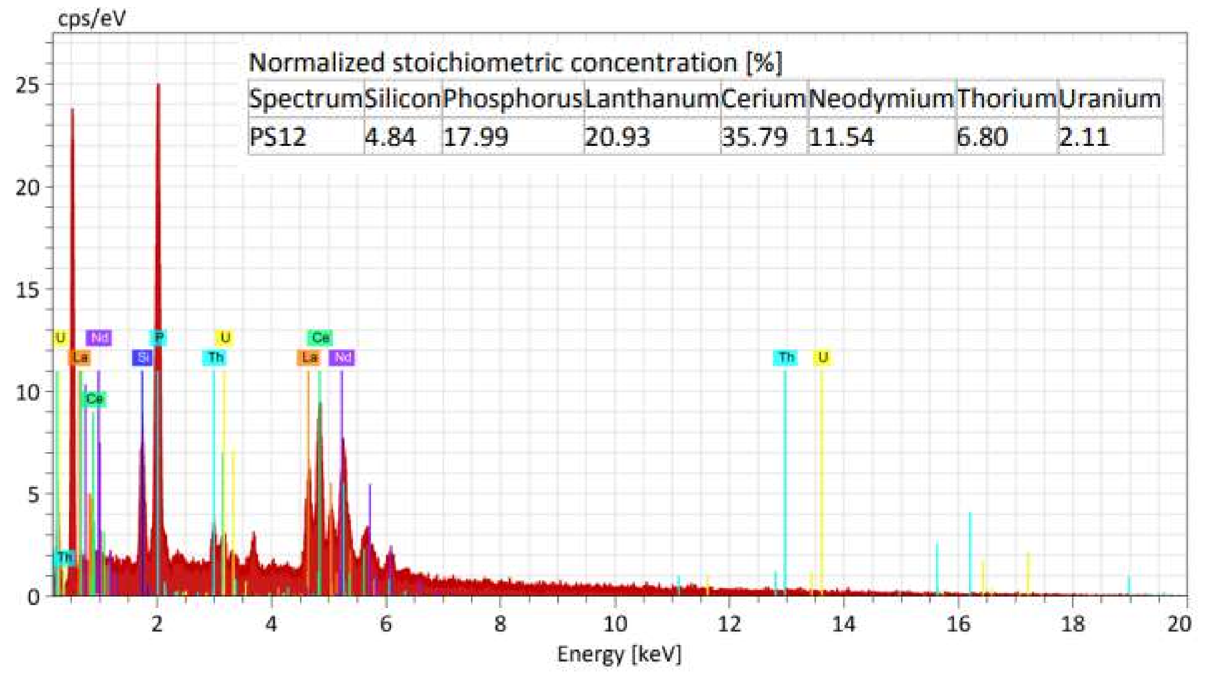


Normalized stoichiometric concentration [%]

Spectrum	Phosphorus	Iron	Lanthanum	Neodymium	Thorium
PS12	13.92	17.66	25.30	16.79	26.33

Fig. 4.4 BSE image and diffractogram showing Thorium (Th) in Muscovite schist (PS-12), Siddreddypalli

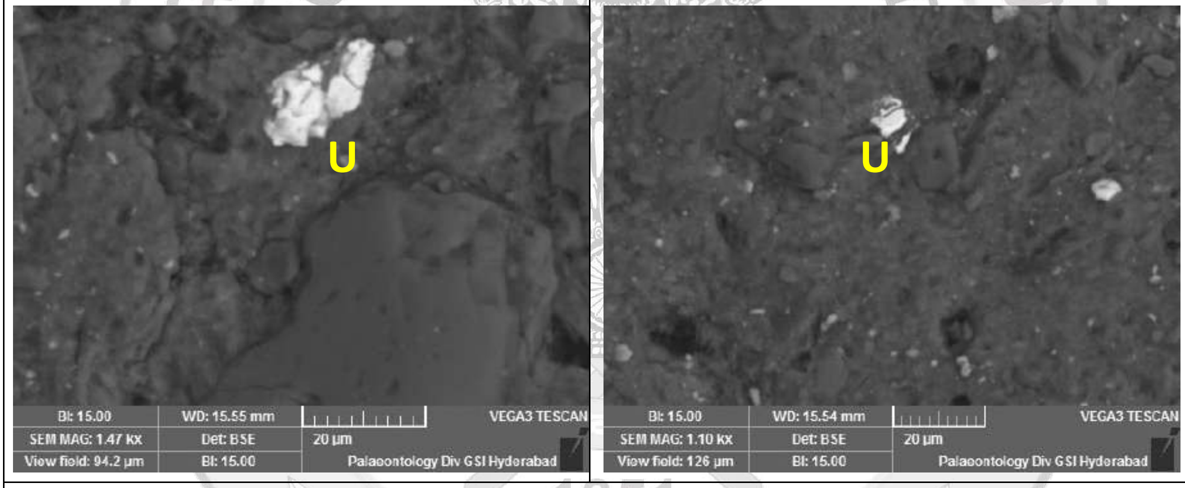


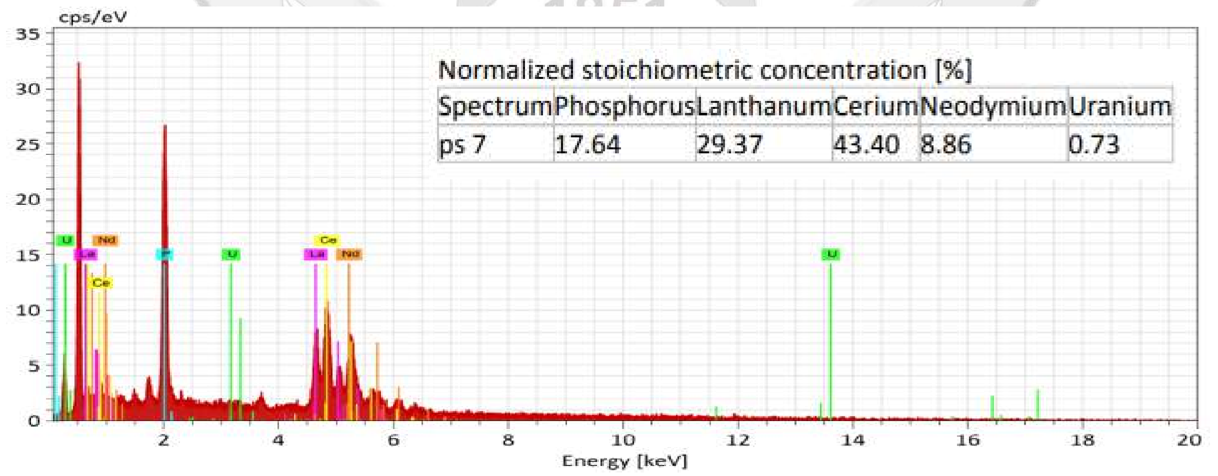


Normalized stoichiometric concentration [%]

Spectrum	Silicon	Phosphorus	Lanthanum	Cerium	Neodymium	Thorium	Uranium
PS12	4.84	17.99	20.93	35.79	11.54	6.80	2.11

Fig. 4.5 BSE image and diffractogram showing Uranium (U) in Muscovite schist (PS-12), Siddreddypalli

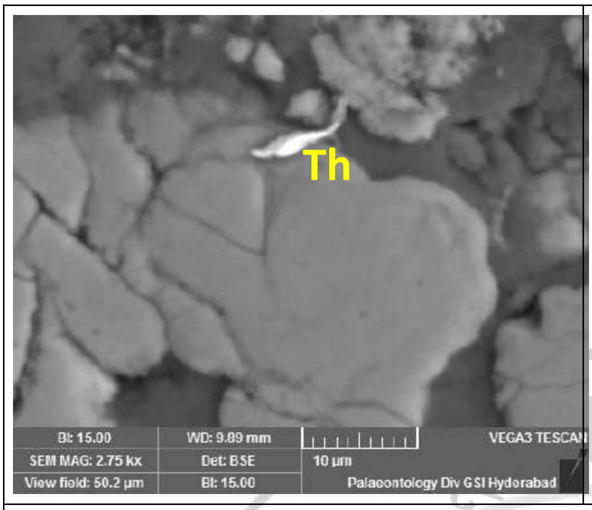


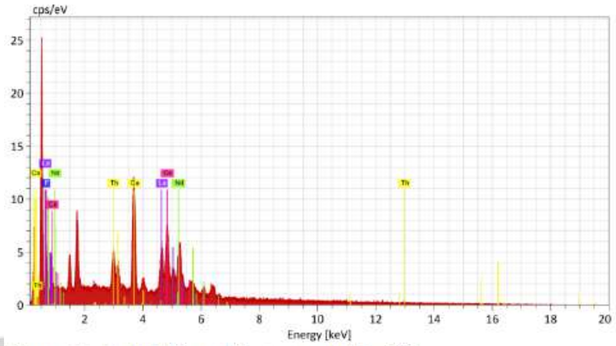


Normalized stoichiometric concentration [%]

Spectrum	Phosphorus	Lanthanum	Cerium	Neodymium	Uranium
ps 7	17.64	29.37	43.40	8.86	0.73

Fig. 4.6 BSE image and diffractogram showing Uranium (U) in Shale (PS-07). Giddangivaripalli

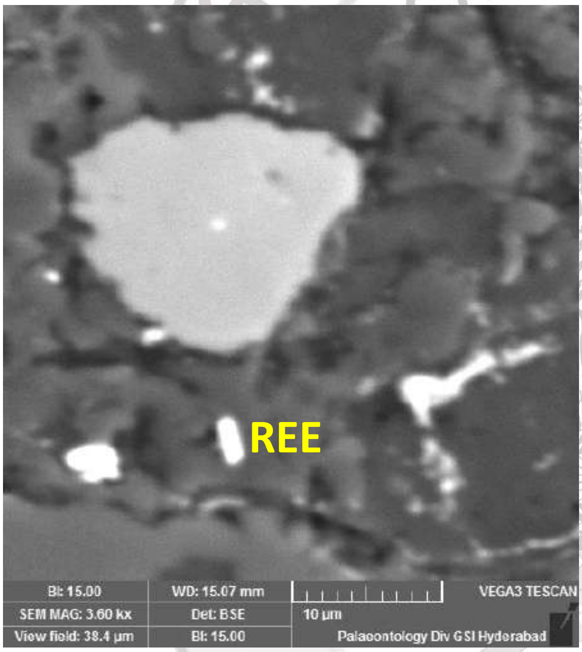


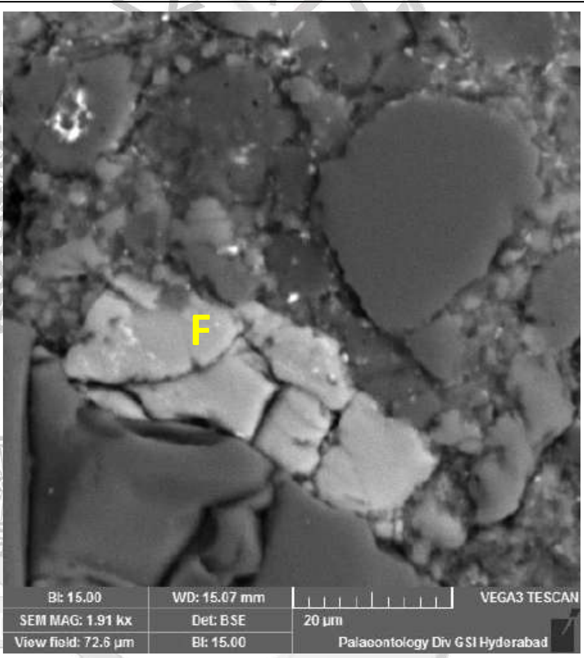


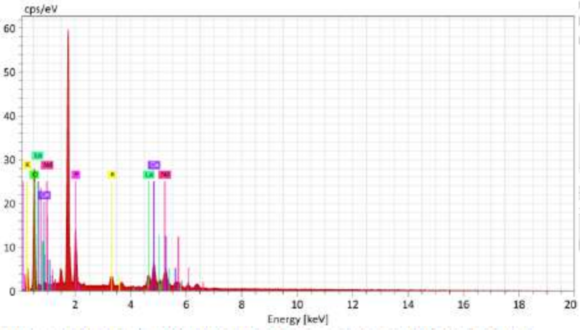
Normalized stoichiometric concentration [%]

Spectrum	Fluorine	Calcium	Lanthanum	Cerium	Neodymium	Thorium
PS_08	6.23	14.31	22.25	35.01	10.12	12.08

Fig. 4.7 BSE image and diffractogram showing Uranium (U) in Shale, Oxidised ore (PS-08). K.Kothala

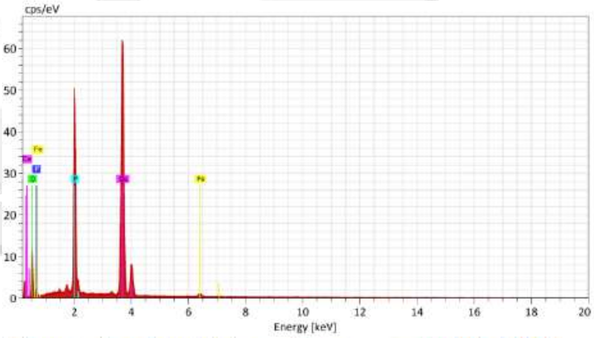






Normalized stoichiometric concentration [%]

Spectrum	Oxygen	P2O5	K2O	La2O3	Ce2O3	Nd2O3
PS9	0.00	32.60	2.85	16.50	34.81	13.24



Normalized stoichiometric concentration [%]

Spectrum	Oxygen	Fluorine	P2O5	CaO	FeO
PS9	0.00	3.07	37.78	57.34	1.80

Fig. 4.8 BSE image and diffractogram showing Rare Earth Elements (Cesium) & Fluorine in Shale, (PS-09). Kanampalli

CHAPTER-5
GEOCHEMICAL INTERPRETATION OF PETROCHEMICAL SAMPLES

5.1 INTRODUCTION

Geochemical studies were conducted with the objective of understanding the magmatic evolution sources of different rock types. To achieve this, a comprehensive set of petrochemical samples was systematically collected, encompassing a representative range of major lithologies and ensuring adequate coverage across the study area. In total, 30 petrochemical samples were gathered, which covered all the significant litho-units (Table 5.1). These samples were obtained from various rock types. This includes Shale, Granite, Hornblende Biotite Gneiss, Dolomite, Stromatolitic Dolomite, Quartzite, intercalated Shale and Dolomite, Muscovite Sillimanite schist, Dolostone. These samples were prepared by grinding to a particle size of -100 mesh and were subjected to major oxide, trace element, and rare earth element (REE) analysis using X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICPMS) methods while Au analysis was carried out MIBK at Chemical Laboratory of Geological Survey of India, Southern Region, Hyderabad. The details of the analysis have been mentioned in Annexure- and Annexure- . Whole rock data has been taken into account. A binary and ternary diagram has been plotted for geochemical classification and tectonic discrimination of the different samples

5.2 GEOCHEMISTRY OF PENINSULAR GNEISSIC COMPLEX-II GROUP OF ROCKS:

Peninsular Gneissic Complex –II group is majorly dominated in the southern part of the study area. the grey hornblende biotite granite gneiss, hornblende biotite granite and Pink granite units. The chemical data of the rock samples reveal an average composition of SiO2 values of 70.38 %, K2O values of 3.82 %, Na2O values of 2.88 %, CaO values of 2.36 % and Al2O3 values of 12.93 %. However, the average Fe2O3, MgO, MnO, TiO2, F and As values are 3.63 %, 1.57 %, 0.06 %, 0.36 %, 778 ppm and 7.88 ppm. Thorium values ranging from 17 ppm to 185 ppm with average of 69.3 and **Uranium values varies from 17.8 ppm to 201.82 ppm with an average of 51.47 ppm ppm** respectively. **Average crustal abundance of the F is 557 ppm, arsenic is 4.8 ppm, Throuim is 10.5 ppm and Uranium is 2.7 ppm.**

5.3 GEOCHEMISTRY OF THE CUDDAPAH SUPER GROUP OF ROCKS:

The cuddapah super group is majorly dominated in the northern part of the study area. The Dolomite, Shale and Basic rock are the major litho units.

The chemical data of the **Dolomite, Stromotolite Dolomite, Dolostone** rock samples reveal an average composition of SiO2 values of 27.73 %, K2O values of 0.98 %, Na2O values of 2.81 %, CaO values of 15.39 % and Al2O3 values of 4.59 %. However, the average Fe2O3, MgO, MnO, TiO2, F and As values are 8.92 %, 14.04 %, 0.06 %, 0.20 %, 235 ppm and 34.4 ppm. **Thorium**

values ranging from 2 ppm to 33 ppm with average of 9.11 and Uranium values varies from 10 ppm to 24 ppm with an average of 14 ppm ppm respectively.

The chemical data of the **Shale** rock samples reveal an average composition of SiO_2 values of 48.07 %, K_2O values of 4.20 %, Na_2O values of 0.14 %, CaO values of 7.48 % and Al_2O_3 values of 11.45 %. However, the average Fe_2O_3, MgO, MnO, TiO_2, F and As values are 8.28 %, 6.97 %, 0.07 %, 0.54 %, 906 ppm and 14 ppm. **Thorium values ranging from 5 ppm to 21 ppm with average of 11 and Uranium values varies from 6 ppm to 24 ppm with an average of 18 ppm ppm** respectively.

The chemical data of the **Basic rock** samples reveal an average composition of SiO_2 values of 40.44 %, K_2O values of 0.81 %, Na_2O values of 1.67 %, CaO values of 4.94 % and Al_2O_3 values of 9.46 %. However, the average Fe_2O_3, MgO, MnO, TiO_2, F and As values are 15.13 %, 17.17 %, 0.17 %, 0.60 %, 106 ppm and 4.5 ppm. Thorium value is 4 ppm and **Uranium value is 12.4 ppm** respectively.

Gulcheru quartzite having Uranium value 5.6 ppm and thorium having 10 ppm

5.4 GEOCHEMISTRY OF MUSCOVITE SILIMANITE SCHIST, VELIGALLU SCHIST BELT:

In the study area Muscovite Silimanite Schist reveal an average composition of SiO_2 values of 50.76 %, K_2O values of 6.26 %, Na_2O values of 0.40 %, CaO values of 0.25 % and Al_2O_3 values of 24.94 %. However, the average Fe_2O_3, MgO, MnO, TiO_2, F and As values are 7.21 %, 3.84 %, 0.14 %, 0.88 %, 198 ppm and 3 ppm. Thorium value is 14 ppm and **Uranium value is 15.60 ppm** respectively. **Average crustal abundance of the F is 557 ppm ans arsenic is 4.8 ppm.**

Table 5.1 Petrochemical samples collected from the Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

Sl. No.	X	Y	ELEVATION	Rock Type	Location
1	78.3919	14.3326	PCS 1/22-23	Dolomite	T Velamavaripalli
2	78.3156	14.3348	PCS 2/22-23	Dolomite	Bhumayagaripalli
2	78.2239	14.4559	PCS 3/22-23	Dolomite	Peddarangapuram
4	78.1223	14.4488	PCS 4/22-23	Stromotolitic dolomite	Gunakalapalli
5	78.2484	14.3615	PCS 5/22-23	Dolomite	Velpula
6	78.459	14.3575	PCS 6/22-23	Dolomite	Vempalli
7	78.3605	14.3104	PCS 7/22-23	Shale	Giddangivaripalli
8	78.2882	14.3128	PCS 8/22-23	Shale	Tummalapali(East of UCIL)
9	78.1465	14.402	PCS 9/22-23	Shale	Nallagunduvaripalli
10	78.2352	14.3513	PCS 10/22-23	Shale	K. Kotala
11	78.2083	14.3485	PCS 11/22-23	Shale	Kanampalli
12	78.3855	14.481	PCS 12/22-23	Shale	Moilalacheruvu
13	78.1312	14.4307	PCS 13/22-23	Shale	Ambakapalli
14	78.1622	14.2546	PCS 14/22-23	Grey granite	Batrepalli
15	78.1623	14.3118	PCS 15/22-23	Granite	Abbanaguntapalli
16	78.1198	14.3389	PCS 16/22-23	Granite	Tappitavaripalli
17	78.1085	14.2755	PCS 17/22-23	Grey hornblende biotite gneiss	Reddigaripalli
18	78.1999	14.3357	PCS 18/22-23	Grey hornblende biotite gneiss	Namalagundu
19	78.4374	14.2693	PCS 19/22-23	Grey hornblende biotite gneiss	Siddreddypalli
20	78.3153	14.267	PCS 20/22-23	Grey hornblende biotite gneiss	Vemupripeta
21	78.2346	14.357	PCS 21/22-23	Dolomite	K Kothala
22	78.2594	14.3261	PCS 22/22-23	Dolostone	Tummalapalli
23	78.4527	14.2749	PCS 23/22-23	Muscovite silimanite schist	Siddreddypalli
24	78.3723	14.352	PCS 24/22-23	Basic Rock	Kotthapalli
25	78.2907	14.3753	PCS 25/22-23	Basic rock	Velpula
26	78.2247	14.3087	PCS 26/22-23	Gniess	Old Kadiri Ghat road
27	78.1155	14.3804	PCS 27/22-23	HBL Granite	Basireddy palli
28	78.2146	14.3461	PCS 28/22-23	Shale dolomite interclation	Kanampalli
29	78.2005	14.3363	PCS 29/22-23	Quartzite	Namalagundu
30	78.1961	14.4007	PCS 30/22-23	Dolomite	Yerragundupalli

CHAPTER-6

SAMPLE MEDIA AND METHODOLOGY

6.1 INTRODUCTION:

For successful interpretation of geoscientific studies, the selection of sampling site and sampling media, methods of sample collection, sample preparation and analytical techniques are very important. Contamination during sample preparation can be a serious source of geochemical analysis. This is most likely to occur during crushing, delumping and grinding and may arise either as cross contamination from previously prepared samples or from the grinding apparatus itself. This contamination was avoided by careful cleaning and by precontaminating the apparatus with the samples to be delumped. The sample media considered for the study are soil (surface), soilprofile (Regolith & C-Horizon), Bedrock/ Petrochemical and water samples (surface & subsurface).

6.2 PRE-FIELD PREPARATION:

Procurement of field equipments and tools required for sampling

(1) For soil sampling, hand scoops, polythene bags, stickers for numbering, permanent marker pens of various colors and portable weighing machine are required. For processing the samples -120 mesh, plastic tub, brush for cleaning the sieves, wooden mortar and pestles for powdering luPS, cloth duster and plastic sheet for covering the samples kept for drying (if required) and PET jars of 500 gm capacity are required.

(2) Geological hammer, pick-axe and spades are required for excavation of pits for soil profiling and sampling.

(3) GPS with batteries is required for precise location of sampling site in the field.

(4) For water sampling, water sampling kit, Flouride/ Arsenic testing kit that includes disposable gloves, disposable syringes, filter papers, disposable filters, pH meter, EC meter, funnel, jerry can, plastic bottles of 1000 ml, 100 ml & 60 ml size, Suprapurnitric acid (HNO_3), potassium dichromate ($K_2Cr_2O_7$) and Millipore water is required.

6.3 FIELD INVESTIGATIONS:

With the perception of problem growing in the area related to water which may be due to geogenic/anthropogenic factors. Geo-scientific studies of the Tummalapalli area, Y.S.R Kadapa and Anantapur districts, in parts of toposheets 57J/3 and 57J/7 was taken up for one field season (FS2022-23) so that the zones containing uranium can be demarcated and identification of the factor causing contamination of uranium and other trace elements, role of structures and mining activity can be delineated and remedial measures suggested.

Various thematic maps, like geomorphological, lineament-fracture, drainage and land use land cover maps were prepared in 1: 25,000 scale with the help of limited field checks in order to validate the control and effect of the mining activity in the area. Compilation of existing data consisting of exploration, groundwater level and groundwater quality with geo-referencing information. To under stand the study in better wat prepred spatial distribution/ point anomaly maps of Fluoride and Arsenic in subsurface water and soil, bed rock collected in the study area.

6.4 WATER SAMPLING AND ANALYTICAL METHODS AND TECHNIQUES:

As we know that groundwater is an important source of drinking water and much more vulnerable to fluoride and arsenic contamination than surface waters because of the greater impacts of water-rock reactions in aquifers. Therefore, pre-monsoon and post monsoon groundwater (Borewell & Dugwell) and surface water samples are collected from affected area to know the water rock interaction and the role of anthropogenic activity.

Before collecting sample from a location, the local population was contacted for any known cases of dental/skeletal deformities or prevalence of joint/back pains in the locality. This led to identification of more affected localities and persons thus, making the study more fruitful and directed. Ground water samples were drawn from open dug well or tube wells. Depth of the hand puPS, dug wells and borewells varied widely. Collected surface water and Ground water samples (pre & post monsoons) in three different sample bottles; 1 x 1000 ml bottle unfiltered water for major ions analysis, 1 x 100 ml bottle filtered water ICP-MS and ICP-AES analysis and 1 x 100 ml bottle for mercury analysis. Location of each sample point was registered properly in terms of latitude and longitude with the help of GPS. Generally, bore wells/hand puPS and dug wells, which were in use, by quite a good number of people for potable water were targeted for the purpose of ground water sampling. After pumping out ground water from a tube well for 4 to 5 minutes, water sample was collected in collection bottles. The surface water samples were collected from the middle portion of the water body as far as practicable. 1 ltr sample for major ions, 100 ml for trace elements analyses and 60ml for mercury analyses was collected for each sample. Due care has been taken to avoid any type of contamination during sampling.

After collection of each sample, certain preservatives were added to the water before air and watertight packing, so that determination of one constituent does not affect the determination of other constituents at a later date. In samples for trace elements determination in laboratory, 1ml of concentrated Suprapur nitric acid was added in each sample water to maintain pH below 2. Similarly, in each 1 ml pottasium dichromate was added to samples collected for mercury analysis.

6.5 SOIL, REGOLITH AND C-HORIZON, BEDROCK SAMPLING AND ANALYTICAL METHODS, TECHNIQUES EMPLOYED

100 nos of Soil samples collected in grid pattern, the soil samples collected are mainly slope wash samples Soil sample studies are used to determine the degree of chemical weathering and the movement of elements from the parent rock to the soil. 20 nos of Soil profile studies from two different depths related samples were taken from each sampling site i.e. Regolith sample denoted by (R) from 0-25 cm (excluding materials from the organic and alluvium and colluviums layer where ever present). It reflects variation in geogenic composition of the uppermost layer of the Earth crust and a soil C-horizon (C) sample within a depth range of 50 to 200cm just above the bed rock. Comparison of the soil and regolith would give information about elemental behavior in weathering or pedogenic process, environmental changes affecting layer of the Earth’s crust. R and C horizon will also be carried out to know the depth and dispersion pattern of soil. Concentration of elements along soil horizons is the important proxy to study the geogenic source and its dispersion pattern of elements which are helpful in geo-environmental studies. 30 nos of petrochemical samples (PCS/BRS) collected to know the source of magmatic evolution of the rock types. 30 nos of thin polished sections study for petrographic, EPMA and SEM studies. Spatial analysis of thematic maps like geomorphological and land use land cover map, drainage map in GIS will be used to establish spatial relationship. The association of uranium and other associated toxic elements in groundwater with granites and volcanic rocks occurs because of the relative abundance of minerals in these rocks.

6.6 SAMPLE PROCESSING

Soil samples are collected from the suitable site observed within the study area as such to maintain the uniformity and to cover all possible lithologies where well developed soil profile over its parent rock from which it has developed can be observed. About 5 kg of sample from each location was brought from field to the camp, sun dried and delumped to break the agglutination. All the materials used for delumping one sample were washed with water and dried up before delumping the next sample. Utmost care was taken to carry out delumping in such a fashion that no grain was grinded. Thereafter, samples were sieved through 120 mesh to collect the -120 fraction. The sieving was carried out in such a way that the maximum clay fraction could be collected. Five hundred gram of sample was collected for each sample then packed in to containers with systematic labelling. 500 gm of composite sample was sent to Chemical Division, SR for chemical analysis. During sample preparation, every care was taken to rigorously check the propagation of contamination from one sample to other.

CHAPTER-7

SOIL, REGOLITH AND C-HORIZON CHEMISTRY

7.1 INTRODUCTION:

The soil is a complex open system, and its generation starts with weathering of parent material and goes on along with pedogenetic processes induced by biotic and abiotic factors. The precipitations and temperature besides the topographic features are the main factors controlling the weathering of parent material and the development of new mineral phases which could coexist with their precursor minerals. The mineralogical composition of parent material, its structure and texture are also important features involved in the weathering evolution trends. The soil generation takes place either by mineral dissolution or transformation with the loss and apparent gains of elements due to their different geochemical behavior during the weathering of parent material. Soils in the study area display variations in terms of particle size distribution, color and surface horizon depth. Differences in the soils represent the effects of parent material because they developed under similar climate, topographical position and land use-vegetation conditions. Based on the existing data base of soil map of Y.S.R Kadapa and Ananthapur district of Andhra Pradesh is majorly clasiified into three dominant type of soils (Inceptisol, Alfisol and Vertisol) mixed red and shallow black with medium and deep black soils (Fig.7.1).

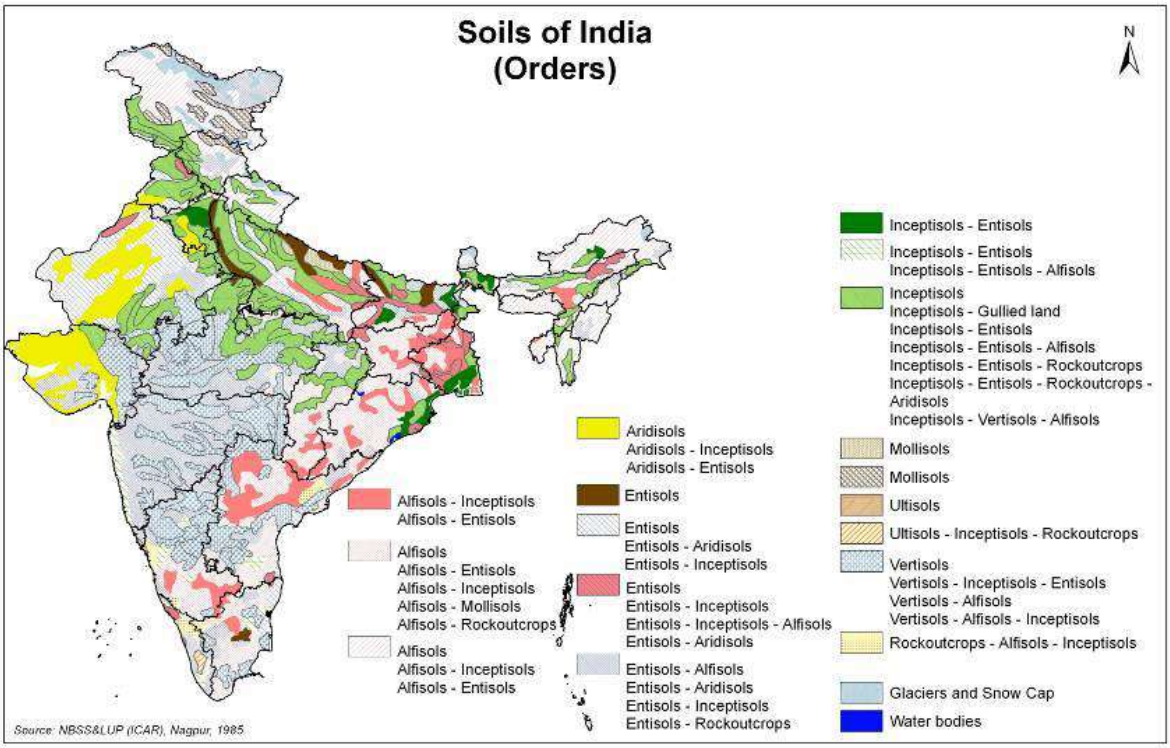
Inceptisol is a soil of semiarid to humid environments which usually reflect only moderate degree of soil erosion and development. Inceptisol soil is a weakly-grown soil. These soils expose minimal horizon development. With inceptisol, some color changes may be conspicuous between the transpiring horizons, and the beginnings of a B horizon may be observed with the deposit of small amounts of salts, clay, and organic substance. **Alfisols** form in semi-arid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility. "Alf" refers to aluminium (Al) and iron (Fe). **Vertisol** is a high content of expansive clay minerals, many of them known as montmorillonite that form deep cracks in drier seasons or years typically form from highly basic rocks in climates that are seasonally humid climatic conditions. In traditional soil nomenecluture map shows that the very to medium shallow red gravelly, medium to deep clay calcareous soil to alluvial black soils with salt effected.

The study area is characterized by several soil types, including black cotton, red ferruginous, brown alluvial, and sandy loams. The soil composition shows variations in terms of particle size distribution, color and surface horizon depth. Differences in the soils represent the effects of parent material because they developed under similar climate, topographical position and landuse-land pattern conditions and it is also influenced by different litho horizons and the weathering of various rock formations. The colour of the soil is indicative of the underlying geology and weathering processes. The pink granite, grey biotite hornblende granite gneiss of PGC-II, Papaghni &Chitravati Group of rocks, and basic intrusive contribute to the colour variations. Approximately 40 percent of the area is underlain by shale from the Tadpatri Formation, which gives rise to black and dark grey clayey soils. These soils tend to be shallow in the piedmont regions but deeper in the plain areas. The colour remains relatively consistent up to depths of 2 to 3 meters. In limestone and dolomite areas, the soil is black to grey in colour, containing calcareous nodules and kankar. In volcanic zones, particularly in the southern and central parts of the area, black soils with high clay content are observed. These soils have excellent water retention capacity and are generally fertile, although some upland areas may exhibit lower fertility. Black soils are fine-grained and rich in calcium and magnesium carbonates. They have a high moisture-holding capacity and become sticky when wet. Fertile black soils are typically found in valleys, while the rock types in this section are often covered by a thin soil layer. Red ferruginous and reddish-brown soils are common on quartzite and granite/gneiss, especially near hills. Lateritic nodules are extensively developed on top of ferruginous quartzite and granite. These nodules are porous, reddish-brown, and have a clay-like appearance. They are covered by a hard protective limonitic crust on the exposed surface, which is typically irregular and rough.

Total 107 nos. of soil and 20 nos of soil profile (Regolith and C-Horizon) samples collected from 1000 sq. km area in gridded pattren and soil samples collected from each grid representing the area (Fig.7.2-7.9). Samples were collected according to the methodology described in the above section. The soil type in the area is mostly black cotton soil silty to silty sand and colour varies from reddish brown to brown and sometimes grey colour. At some places black cotton soil observed in small patches. Location map of soil samples is given in (Fig.7.10). Statistical summary of the analytical result is given below in (Table-7.1).

Profiles developed on the Dolomite, stromotolitic dolomite, Dolostone, Shale , basic rocks of Cuddapah group of rocks and Gneiss and granites of PGC-II group of rocks presence of secondary calcium rich veins, as a result of decomposition and fragmentation it indicates in the form of calcreate. Soil color was closely related to the parent materials, in the Granitic terrain soil profiles, the soil had a weak or moderately developed Regolith horizon with a granular, angular in structure and a C horizon partially weathred with massive in nature.

Fig.7.1 Soil map of the India showing different soils (Inceptisol, Alfisol and Vertisol)



Source: NBSS&LUP (ICAR), Nagpur, 1985

Detail inventory, analytical data (Major, REE and Trace) for soil, Regolith and C-Horizon shown in Annexure-II, III, V &VI.

Fig.7.2: Field photograph showing Soil sample collected from Dugganavaripalli

Fig.7.3: Field photograph showing Soil sample collected from Giddangivaripalli

Fig.7.4: Field photograph showing brownish red (silty lomy soil sample collected near Tummalapalli

Fig.7.5: Field photograph showing Red soil near UCIL

Fig.7.6: Field photograph showing collection of brown soil in Siddareddy palli.

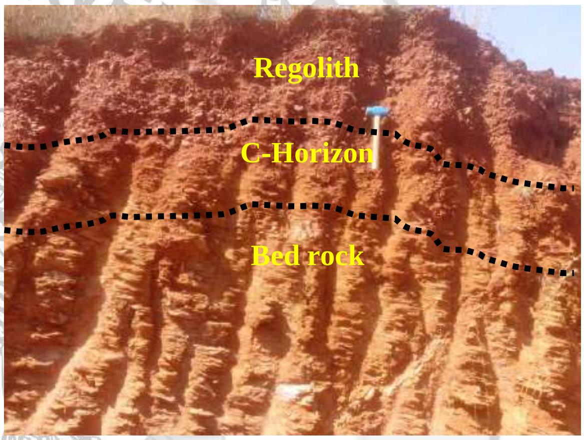


Fig.7.7: Field photograph showing Soil profile (R & C) sample developed from Basic rock,Puttakonamma area

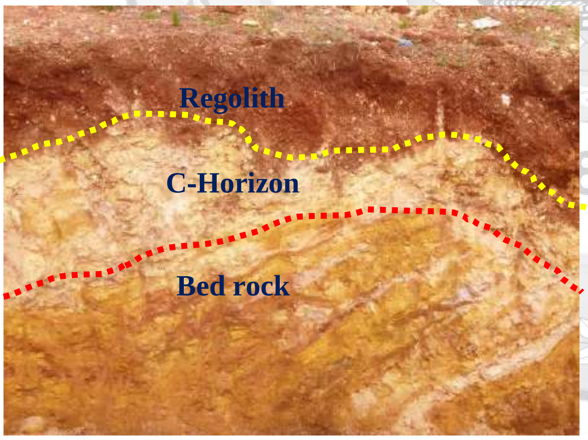


Fig.7.8: Field photograph showing Soil profile (R & C) sample developed from Dolomite and shale intercalations, near UCIL Plant

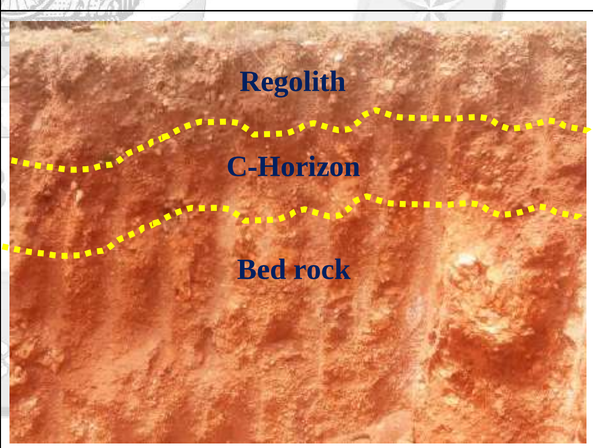


Fig.7.9: Field photograph showing Soil profile (R & C) sample developed from Granitic gneiss/granites of PGC-II group of rocks, near Kondagattupalli.

Fig.7.10 Location map showing Soil (S1), Reolith, C-horizon (SP1) and Bed rock (BRS1) in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

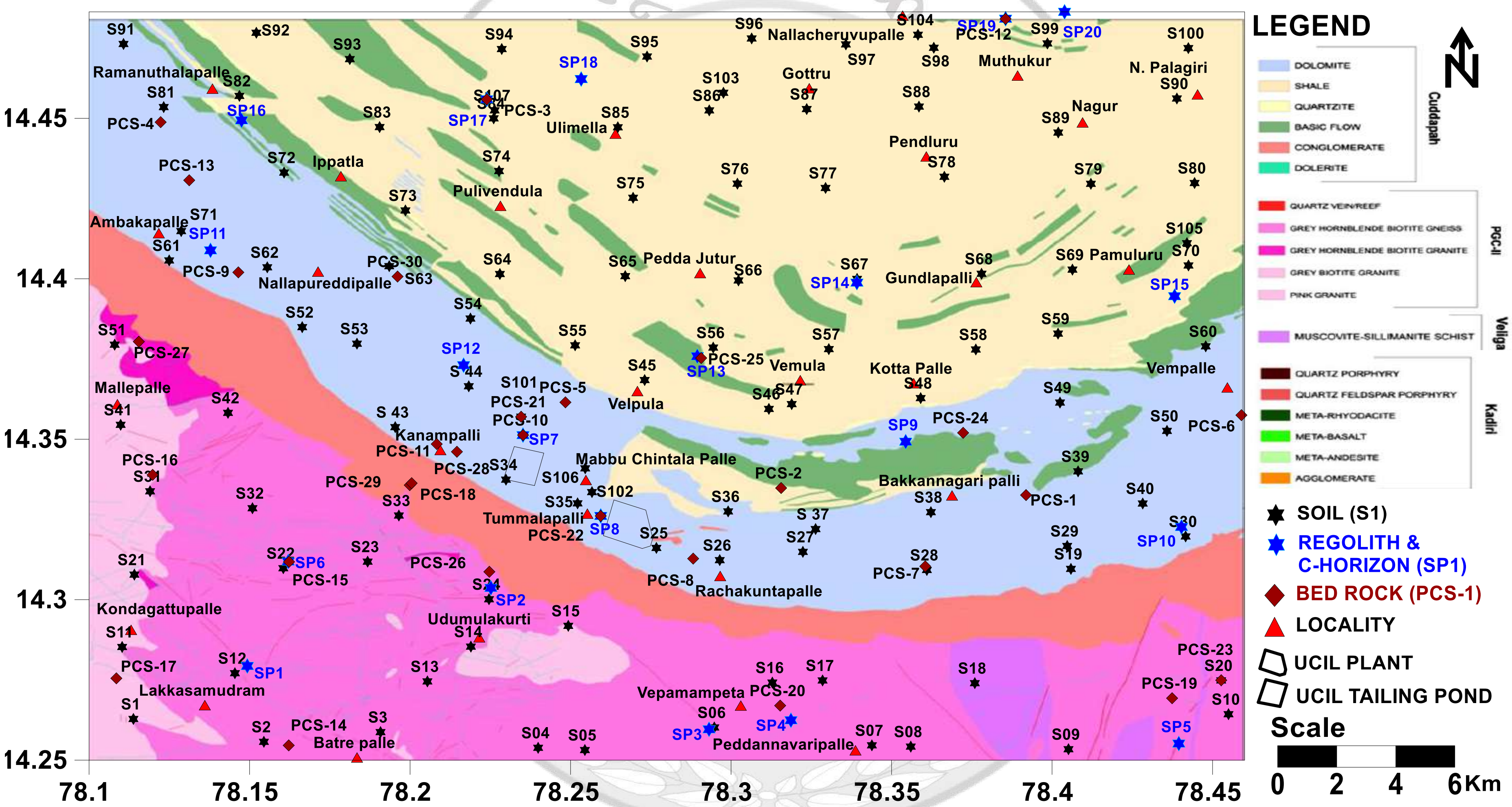


Table :7.1 Statistical parameters for the major oxides (%) ,REE (ppm) and trace elements (ppm) of soil samples, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

Oxides	Minimum	Maximum	Range	Mean	Median	Mode	Standard Deviation	Kurtosis	Skewness	Crustal Abundance (R. L. Rudnick and S. Gao, 2004)		
										Crustal abundance	No. of samples	% of samples
SiO_2	28.96	73.47	44.51	56.23	56.62	63.25	6.54	2.05	-0.63	66.6	4	3.7
Al_2O_3	9.24	19.83	10.59	13.79	12.87	11.83	2.57	-0.58	0.62	15.4	28	26.2
Fe_2O_3 (T)	2.75	12.34	9.59	6.78	6.84	7.70	1.92	0.11	0.13	5.04	86	80.4
MnO	0.04	0.23	0.19	0.11	0.11	0.12	0.04	-0.20	0.31	0.1	58	54.2
MgO	0.32	8.18	7.86	2.44	2.28	2.59	1.32	3.03	1.18	2.48	48	44.9
CaO	0.42	22.38	21.96	3.57	2.58	0.74	3.10	12.40	2.71	3.59	41	38.3
Na_2O	0.05	3.53	3.48	0.90	0.47	0.28	0.91	0.57	1.30	3.27	2	1.9
K_2O	0.55	5.38	4.83	2.18	2.07	2.14	1.07	0.72	0.96	2.8	29	27.1
TiO_2	0.49	1.51	1.02	0.85	0.82	0.83	0.21	0.80	0.98	0.64	92	86.0
P_2O_5	0.05	0.51	0.46	0.14	0.13	0.08	0.07	7.29	2.11	0.15	35	32.7
La	22.51	122.36	99.85	63.78	63.54	#N/A	21.19	0.10	0.67	31	105	98.1
Ce	41.84	244.94	203.10	86.11	76.90	#N/A	36.67	4.07	1.83	63	78	72.9
Pr	4.90	26.04	21.13	10.03	9.24	5.74	3.81	2.72	1.57	7.1	88	82.2
Nd	17.95	90.42	72.47	36.32	33.19	#N/A	13.05	4.29	1.84	27	89	83.2
Eu	0.82	2.30	1.47	1.35	1.33	1.11	0.27	0.78	0.63	1	99	92.5
Sm	3.61	15.75	12.15	6.71	6.21	4.96	2.11	4.15	1.68	4.7	95	88.8
Tb	0.50	3.69	3.19	0.97	0.92	0.95	0.36	29.25	4.40	0.7	96	89.7
Gd	3.20	13.45	10.25	5.88	5.55	5.46	1.60	5.51	1.77	4	99	92.5
Dy	3.20	14.13	10.93	5.79	5.57	9.94	1.65	6.95	2.03	3.9	102	95.3
Ho	0.65	2.86	2.22	1.13	1.06	1.00	0.36	6.23	2.05	0.83	94	87.9
Er	1.78	9.75	7.98	3.55	3.27	3.05	1.22	7.89	2.27	2.3	98	91.6
Tm	0.28	1.90	1.61	0.57	0.53	0.47	0.23	10.94	2.65	0.3	101	94.4
Yb	1.86	13.84	11.98	3.94	3.44	2.78	1.77	9.96	2.62	1.96	105	98.1
Lu	0.27	2.50	2.23	0.66	0.57	0.49	0.33	10.34	2.71	0.31	105	98.1

Trace elements (ppm)	Minimum	Maximum	Range	Mean	Median	Mode	Standard Deviation	Kurtosis	Skewness	Crustal Abundance (R. L. Rudnick and S. Gao, 2004)		
										Crustal abundance	No. of samples	% of samples
Ba	271.00	11972.00	865.57	514.00	628	38	35.5	271.00	11972.00	865.57	514.00	628
Ga	11.00	33.00	19.00	19.00	17.5	67	62.6	11.00	33.00	19.00	19.00	17.5
Sc	2.00	22.00	10.87	11.00	14	26	24.3	2.00	22.00	10.87	11.00	14
V	34.00	221.00	110.79	114.00	97	64	59.8	34.00	221.00	110.79	114.00	97
Pb	1.00	38.00	21.29	21.00	17	81	75.7	1.00	38.00	21.29	21.00	17
Ni	7.00	207.00	60.04	61.00	47	74	69.2	7.00	207.00	60.04	61.00	47
Co	6.00	41.00	19.97	19.00	17.3	64	59.8	6.00	41.00	19.97	19.00	17.3
Rb	46.00	376.00	119.01	101.00	84	73	68.2	46.00	376.00	119.01	101.00	84
Sr	44.00	618.00	178.42	155.00	320	9	8.4	44.00	618.00	178.42	155.00	320
Y	14.00	38.00	29.02	29.00	21	100	93.5	14.00	38.00	29.02	29.00	21
Zr	114.00	2027.00	497.48	349.00	193	97	90.7	114.00	2027.00	497.48	349.00	193
Nb	9.00	56.00	18.60	15.00	12	83	77.6	9.00	56.00	18.60	15.00	12
Cr	23.00	866.00	131.24	106.00	92	73	68.2	23.00	866.00	131.24	106.00	92
Cu	10.00	118.00	56.74	55.00	28	94	87.9	10.00	118.00	56.74	55.00	28
Zn	10.00	89.00	41.91	42.00	67	5	4.7	10.00	89.00	41.91	42.00	67
Be	0.78	7.00	2.54	2.24	2.1	61	57.0	0.78	7.00	2.54	2.24	2.1
Ge	0.65	3.24	1.28	1.22	1.4	30	28.0	0.65	3.24	1.28	1.22	1.4
Mo	0.25	3.57	0.70	0.55	1.1	16	15.0	0.25	3.57	0.70	0.55	1.1
Hf	3.43	50.34	17.46	16.19	5.3	102	95.3	3.43	50.34	17.46	16.19	5.3
Ta	0.10	5.98	1.63	1.25	0.9	63	58.9	0.10	5.98	1.63	1.25	0.9
W	0.25	8.13	1.00	0.25	1.9	19	17.8	0.25	8.13	1.00	0.25	1.9
Ag	1.00	1.00	1.00	1.00	0.053	NDL	NDL	1.00	1.00	1.00	1.00	0.053
Cd	1.00	3.00	1.14	1.00	0.09	14	13.1	1.00	3.00	1.14	1.00	0.09
Au(ppb)	0.03	0.23	0.03	0.03	0.0015	4	3.7	0.03	0.23	0.03	0.03	0.0015

Se	0.10	0.51	0.31	0.29	0.09	107	100.0	0.10	0.51	0.31	0.29	0.09
Li	2.50	198.22	27.53	22.84	24	46	43.0	2.50	198.22	27.53	22.84	24
In	0.02	0.12	0.05	0.05	0.056	17	15.9	0.02	0.12	0.05	0.05	0.056
Sb	0.10	0.93	0.39	0.40	0.4	53	49.5	0.10	0.93	0.39	0.40	0.4
Te	0.01	0.20	0.05	0.04			0.0	0.01	0.20	0.05	0.04	
Cs	1.00	5.59	2.98	3.04	4.9	1	0.9	1.00	5.59	2.98	3.04	4.9
Tl	0.20	1.95	0.58	0.46	0.9	19	17.8	0.20	1.95	0.58	0.46	0.9
Bi	0.05	2.19	0.23	0.18	0.16	61	57.0	0.05	2.19	0.23	0.18	0.16
Hg	2.50	88.00	5.93	2.50	0.05	32	29.9	2.50	88.00	5.93	2.50	0.05
U	4.15	50.47	14.76	11.83	2.7	107	100.0	4.15	50.47	14.76	11.83	2.7
Th	4.00	854.00	59.77	16.00	10.5	75	70.1	4.00	854.00	59.77	16.00	10.5
As	0.50	25.00	9.03	8.00	4.8	80	74.8	0.50	25.00	9.03	8.00	4.8
F	50.00	1196.00	288.92	252.00	557	13	12.1	50.00	1196.00	288.92	252.00	557

Table:7.3 Statistical parameters for the major oxides (%), REE (ppm) and trace elements (ppm) of Regolith and C-Horizon samples, YSR Kadapa & Anantapur district, Andhra Pradesh

Oxides	Soil Horizon	Minimum	Maximum	Range	Mean	Median	Standard Deviation	Kurtosis	Skewness
SiO_2	R	32.44	70.12	37.68	50.42	51.18	9.41	0.05	-0.05
	C	29.77	66.33	36.56	44.98	45.96	10.19	-0.45	0.15
Al_2O_3	R	7.84	21.09	13.25	15.35	15.06	4.03	-1.23	-0.15
	C	4.61	28.37	23.76	15.10	13.36	6.32	-0.09	0.62
Fe_2O_3 (T)	R	2.40	15.39	12.99	8.42	7.59	3.74	-0.42	0.40
	C	3.27	16.58	13.31	8.27	7.79	3.68	-0.10	0.70
MnO	R	0.04	0.21	0.17	0.12	0.12	0.05	-0.49	0.50
	C	0.05	0.28	0.23	0.11	0.11	0.06	3.32	1.70
MgO	R	0.41	7.99	7.58	2.72	1.95	2.23	0.92	1.26
	C	0.55	13.22	12.67	3.55	2.34	3.13	3.91	1.79
CaO	R	0.64	15.34	14.70	4.61	2.64	4.87	0.39	1.27
	C	0.48	22.37	21.89	8.15	7.43	7.25	-0.89	0.58
Na_2O	R	0.15	2.56	2.41	0.74	0.50	0.69	2.59	1.78
	C	0.11	1.75	1.64	0.62	0.50	0.47	0.75	1.05
K_2O	R	0.43	5.19	4.76	2.39	1.87	1.42	-0.77	0.60
	C	0.21	3.98	3.77	1.99	1.72	1.23	-1.40	0.18
TiO_2	R	0.39	1.54	1.15	0.78	0.76	0.26	3.10	1.29
	C	0.28	0.93	0.65	0.58	0.53	0.22	-1.27	0.34
P_2O_5	R	0.06	0.18	0.12	0.10	0.10	0.03	1.23	1.28
	C	0.05	0.21	0.16	0.09	0.08	0.04	2.56	1.74
REE (ppm)									
La	R	38.21	111.89	73.68	63.24	57.59	19.53	0.44	0.93
	C	21.03	192.65	171.62	67.58	54.86	45.05	3.89	2.04
Ce	R	36.13	188.45	152.32	81.87	70.10	43.55	1.28	1.43
	C	31.89	359.95	328.06	91.83	61.49	86.00	4.44	2.15
Pr	R	3.77	22.59	18.82	10.62	9.08	5.30	0.56	1.13
	C	3.25	50.22	46.97	11.81	7.42	12.47	5.75	2.52
Nd	R	20.98	74.33	53.35	38.01	33.58	16.20	0.79	1.29
	C	14.08	172.38	158.30	41.85	28.06	41.59	5.99	2.55
Eu	R	0.69	1.97	1.28	1.41	1.34	0.35	-0.51	-0.18
	C	0.44	4.35	3.91	1.37	1.20	0.83	9.04	2.69
Sm	R	3.22	13.69	10.47	7.13	6.28	2.82	1.15	1.32
	C	3.28	26.80	23.51	7.64	5.38	5.87	6.16	2.46
Tb	R	0.51	1.80	1.29	1.01	0.96	0.32	1.26	1.13
	C	0.40	2.53	2.13	0.98	0.81	0.53	2.75	1.61
Gd	R	3.03	11.36	8.33	6.27	5.95	2.19	0.59	0.99
	C	2.87	17.36	14.49	6.14	5.16	3.60	4.34	2.03
Dy	R	3.28	11.10	7.82	6.01	5.54	2.33	0.56	1.17
	C	1.77	14.87	13.11	5.58	4.63	3.08	3.20	1.61
Ho	R	0.57	2.41	1.84	1.18	1.04	0.48	1.43	1.40

	C	0.42	2.45	2.03	1.09	0.89	0.55	0.59	1.08
Er	R	1.98	7.75	5.78	3.68	3.27	1.50	2.09	1.51
	C	1.06	8.21	7.15	3.31	2.83	1.85	1.55	1.35
Tm	R	0.35	1.25	0.90	0.59	0.51	0.24	2.55	1.73
	C	0.20	1.38	1.18	0.51	0.41	0.30	3.21	1.75
Yb	R	2.35	9.87	7.51	4.07	3.41	1.87	4.82	2.23
	C	1.01	9.49	8.48	3.54	2.96	2.17	2.84	1.66
Lu	R	0.37	1.66	1.29	0.67	0.56	0.32	4.43	2.12
	C	0.20	1.48	1.28	0.55	0.45	0.36	2.49	1.70
Trace elements (ppm)									
Ba	R	130.00	6167.00	6037.00	1033.75	452.00	1419.98	9.06	2.83
	C	126.00	18000.00	17874.00	1907.15	433.00	4346.72	10.76	3.25
Ga	R	14.00	30.00	16.00	22.10	22.00	4.78	-1.07	-0.06
	C	11.00	40.00	29.00	22.75	20.00	8.89	-0.43	0.87
Sc	R	8.00	54.00	46.00	27.25	24.50	12.63	-0.08	0.66
	C	15.00	49.00	34.00	28.80	27.00	9.21	0.22	0.87
V	R	31.00	294.00	263.00	125.85	115.5	69.00	2.22	1.48
	C	45.00	230.00	185.00	104.90	102.0	42.75	2.79	1.11
Th	R	4.00	197.00	193.00	30.55	13.00	44.04	11.39	3.17
	C	2.00	138.00	136.00	24.95	9.50	36.19	4.88	2.25
Pb	R	5.00	50.00	45.00	15.25	14.00	10.16	7.02	2.37
	C	1.00	51.00	50.00	17.15	14.00	11.90	2.47	1.57
Ni	R	14.00	753.00	739.00	102.60	62.50	159.29	16.58	3.94
	C	25.00	1325.00	1300.00	126.70	58.00	283.70	19.46	4.39
Co	R	7.00	112.00	105.00	32.75	29.00	22.75	7.55	2.31
	C	6.00	220.00	214.00	39.65	30.00	45.93	13.78	3.55
Rb	R	21.00	364.00	343.00	126.95	106.5	91.18	1.11	1.18
	C	12.00	265.00	253.00	111.45	84.00	82.53	-1.15	0.53
Sr	R	31.00	215.00	184.00	95.25	67.00	58.27	-0.34	1.02
	C	28.00	405.00	377.00	114.90	80.00	109.70	2.51	1.90
Y	R	26.00	52.00	26.00	36.10	34.50	7.51	-0.72	0.41
	C	22.00	67.00	45.00	37.10	33.00	14.15	0.12	1.18
Zr	R	97.00	755.00	658.00	290.10	229.0	165.09	1.90	1.36
	C	66.00	594.00	528.00	203.15	140.0	148.62	1.46	1.47
Nb	R	8.00	58.00	50.00	18.05	13.50	13.14	3.95	2.07
	C	5.00	61.00	56.00	15.25	11.00	13.36	7.14	2.55
Cr	R	49.00	2582.00	2533.00	311.80	135.0	567.17	15.08	3.76
	C	28.00	4066.00	4038.00	335.50	99.50	887.63	19.01	4.32
Cu	R	3.00	102.00	99.00	38.15	35.00	27.07	0.00	0.67
	C	0.50	71.00	70.50	35.48	33.00	24.10	-1.42	0.10
Zn	R	12.00	106.00	94.00	50.35	50.50	24.36	0.08	0.56
	C	13.00	152.00	139.00	54.80	53.00	32.39	3.24	1.44

Be	R	1.36	5.07	3.71	2.91	2.66	1.09	-0.81	0.55
	C	0.74	5.97	5.23	2.87	2.78	1.80	-1.12	0.53
Ge	R	0.82	2.92	2.11	1.63	1.57	0.53	0.39	0.56
	C	0.68	3.33	2.66	1.43	1.03	0.80	0.33	1.22
Mo	R	0.25	5.86	5.61	0.88	0.25	1.38	9.60	3.03
	C	0.25	1.45	1.20	0.54	0.25	0.43	-0.45	1.11
Sn	R	2.50	2.50	0.00	2.50	2.50	0.00	#DIV/	#D
	C	2.50	2.50	0.00	2.50	2.50	0.00	#DIV/	#DIV
Hf	R	2.84	27.82	24.99	12.40	12.76	6.36	0.16	0.60
	C	2.08	48.31	46.23	10.92	8.30	10.02	10.65	2.93
Ta	R	0.35	1.71	1.37	0.93	0.91	0.41	-0.95	0.29
	C	0.23	1.75	1.52	0.73	0.68	0.42	0.45	0.90
W	R	0.25	15.51	15.26	3.70	1.45	4.49	0.99	1.35
	C	0.25	15.60	15.35	4.05	1.77	4.67	0.76	1.32
U	R	3.74	32.98	29.24	13.82	13.42	8.33	0.14	0.80
	C	2.91	40.86	37.95	13.05	12.65	9.21	3.63	1.64
F	**R**	50.00	647.20	597.20	318.48	312.0	185.77	-0.86	0.11
	C	109.60	771.20	661.60	415.25	365.2	197.07	-1.03	0.41
As	**R**	2.00	37.00	35.00	11.50	9.00	9.58	0.98	1.10
	C	0.50	29.00	28.50	9.13	7.00	6.65	3.09	1.63
Ag	**R**	1.00	1.00	0.00	1.00	1.00	0.00	#DIV/	#DIV/
	C	1.00	1.00	0.00	1.00	1.00	0.00	#DIV	#DIV
Cd	**R**	1.00	5.00	4.00	2.00	1.00	1.41	0.18	1.24
	C	1.00	5.00	4.00	2.20	1.50	1.40	-1.18	0.63
Se	**R**	0.24	0.51	0.27	0.36	0.34	0.08	-0.75	0.60
	C	0.21	0.53	0.32	0.34	0.35	0.08	0.77	0.37
Li	**R**	6.71	81.84	75.13	37.43	30.65	21.44	-0.21	0.93
	C	14.06	90.07	76.01	37.75	30.46	22.25	0.46	1.15
In	0.04	0.09	0.05	0.06	0.06	0.02	-0.67	0.35	0.04
	0.02	0.11	0.10	0.06	0.07	0.03	-0.37	0.01	0.02
Sb	0.25	0.84	0.59	0.51	0.51	0.18	-0.87	0.20	0.25
	0.10	1.32	1.22	0.51	0.41	0.28	2.78	1.40	0.10
Te	0.01	0.28	0.27	0.06	0.06	0.06	11.50	2.99	0.01
	0.01	0.22	0.21	0.07	0.07	0.05	1.68	1.06	0.01
Cs	1.00	14.73	13.73	4.02	3.21	2.76	13.06	3.32	1.00
	1.00	14.55	13.55	3.74	3.18	3.14	7.23	2.46	1.00
Tl	0.14	1.77	1.63	0.59	0.40	0.44	1.41	1.47	0.14
	0.05	1.46	1.41	0.52	0.35	0.43	-0.08	1.06	0.05
Bi	0.05	1.19	1.14	0.25	0.17	0.26	9.22	2.70	0.05
	0.05	1.63	1.58	0.29	0.24	0.36	11.04	3.00	0.05
Hg	2.50	14.00	11.50	5.10	2.50	3.69	0.02	1.12	2.50
	2.50	10.00	7.50	3.95	2.50	2.57	1.48	1.65	2.50
Au	0.03	15.00	14.98	9.79	15.00	7.28	-1.72	-0.68	0.03
	0.03	15.00	14.98	9.77	15.00	7.31	-1.72	-0.68	0.03

Table 7.2 Correlation matrix of Major oxides, Tace elements and REE of soil samples collected from Tummalapalli area, Y.S.R. Kadapa and Ananthapur District, Andhra Pradesh

	SiO2	Al2O3	l Fe as Fe	l Mn as M	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	F ppm	As ppm	Ba	Ga	Sc	V	Th	Pb	Ni	Co	Rb	Sr	Y	Zr	Nb	Cr	Cu	Zn	Be	Ge	Hf	Ta	U	La	Ce	Pr	Nd	Eu	Sm	Tb	Gd	Dy	Ho	Er	Tm	Yb	Lu	Cd	Au (ppm)	Se ppm	Li	Mo	In	Sb	Te	Cs	W	Tl	Bi	Hg
SiO2	1.00																																																											
Al2O3	0.32	1.00																																																										
Total Fe	-0.45	-0.43	1.00																																																								
Total Mn	-0.41	-0.46	0.78	1.00																																																						
MgO	-0.60	-0.60	0.46	0.45	1.00																																																			
CaO	-0.84	-0.43	0.12	0.16	0.43	1.00																																																	
Na2O	0.44	0.76	-0.66	-0.69	-0.57	-0.34	1.00																																																
K2O	0.61	0.58	-0.73	-0.60	-0.55	-0.48	0.71	1.00																																														
TiO2	-0.05	-0.28	0.53	0.48	0.09	-0.01	-0.27	-0.42	1.00																																												
P2O5	-0.28	-0.22	0.16	0.29	0.19	0.25	-0.22	-0.10	0.20	1.00																																										
LOI	-0.89	-0.62	0.51	0.52	0.65	0.76	-0.72	-0.75	0.08	0.27	1.00																																									
F ppm	-0.07	-0.48	0.12	0.19	0.30	0.15	-0.43	-0.27	0.14	0.14	0.26	1.00																																								
As ppm	0.02	0.03	0.03	0.11	-0.06	-0.06	-0.08	-0.02	-0.01	0.00	0.02	0.13	1.00																																							
Ba	0.08	-0.24	0.08	0.03	0.08	-0.09	-0.20	-0.10	-0.05	-0.03	0.06	0.30	-0.16	1.00																																						
Ga	0.04	0.56	0.01	-0.13	-0.11	-0.36	0.28	0.19	-0.28	0.00	-0.17	-0.22	-0.03	-0.20	1.00																																					
Sc	-0.71	-0.57	0.77	0.71	0.79	0.46	-0.63	-0.78	0.37	0.18	0.75	0.16	-0.09	0.06	-0.05	1.00																																				
V	-0.40	-0.44	0.88	0.81	0.43	0.14	-0.62	-0.63	0.65	0.24	0.45	0.15	0.04	0.10	-0.12	0.74	1.00																																			
Th	0.42	0.44	-0.56	-0.54	-0.47	-0.30	0.66	0.66	-0.21	-0.23	-0.53	-0.27	-0.01	-0.11	0.01	-0.59	-0.56	1.00																																		
Pb	-0.10	0.17	0.16	0.25	-0.01	-0.04	-0.18	-0.20	-0.01	0.25	0.09	0.09	0.17	-0.13	0.38	0.08	0.17	-0.53	1.00																																	
Ni	-0.43	-0.43	0.60	0.57	0.53	0.18	-0.60	-0.56	0.07	0.06	0.56	0.18	0.06	0.22	-0.10	0.64	0.52	-0.50	0.10	1.00																																
Co	-0.54	-0.60	0.87	0.79	0.53	0.31	-0.66	-0.73	0.52	0.29	0.63	0.23	0.07	0.17	-0.22	0.81	0.85	-0.53	0.07	0.67	1.00																														
Rb	0.53	0.37	-0.62	-0.56	-0.48	-0.41	0.42	0.73	-0.46	-0.12	-0.51	-0.03	0.00	0.16	0.23	-0.68	-0.59	0.36	0.03	-0.43	-0.60	1.00																													
Sr	-0.01	0.53	-0.36	-0.41	-0.25	0.07	0.52	0.13	-0.12	-0.07	-0.21	-0.19	-0.07	-0.09	0.21	-0.24	-0.31	0.08	0.26	-0.30	-0.35	0.06	1.00																												
Y	-0.15	-0.15	0.08	0.17	0.34	0.00	-0.44	-0.03	-0.15	0.23	0.27	0.23	-0.04	-0.09	0.37	0.18	0.05	-0.25	0.31	0.12	0.00	0.20	-0.28	1.00																											
Zr	0.58	0.61	-0.66	-0.57	-0.63	-0.42	0.78	0.74	-0.12	-0.27	-0.74	-0.34	-0.02	-0.17	0.01	-0.72	-0.60	0.85	-0.38	-0.60	-0.67	0.44	0.28	-0.31	1.00																										
Nb	0.44	0.66	-0.60	-0.64	-0.58	-0.37	0.78	0.67	-0.24	-0.20	-0.61	-0.31	-0.02	-0.21	0.41	-0.65	-0.62	0.76	-0.18	-0.65	-0.66	0.54	0.27	-0.10	0.77	1.00																									
Cr	-0.29	-0.25	0.34	0.35	0.42	0.12	-0.31	-0.36	-0.07	-0.07	0.36	0.08	0.07	0.06	-0.08	0.45	0.27	-0.27	0.03	0.86	0.44	-0.31	-0.15	0.02	-0.34	-0.41	1.00																								
Cu	-0.49	-0.48	0.86	0.72	0.40	0.25	-0.68	-0.76	0.47	0.21	0.60	0.19	0.05	0.14	-0.15	0.70	0.80	-0.55	0.19	0.60	0.88	-0.56	-0.28	0.01	-0.66	-0.64	0.37	1.00																							
Zn	-0.46	-0.29	0.49	0.44	0.32	0.31	-0.33	-0.45	0.34	0.60	0.46	0.08	-0.13	0.01	0.06	0.55	0.46	-0.39	0.21	0.36	0.58	-0.40	-0.04	0.10	-0.47	-0.41	0.17	0.53	1.00																						
Be	0.29	0.76	-0.48	-0.53	-0.47	-0.35	0.68	0.57	-0.40	-0.10	-0.50	-0.30	0.06	-0.10	0.63	-0.54	-0.52	0.53	0.08	-0.53	-0.60	0.45	0.38	0.00	0.55	0.78	-0.36	-0.53	-0.26	1.00																					
Ge	0.06	-0.02	0.19	0.19	0.02	-0.15	-0.14	-0.03	0.01	-0.17	-0.03	-0.07	0.04	0.17	0.13	0.11	0.24	-0.09	0.07	0.13	0.09	-0.01	-0.10	0.01	-0.13	-0.07	0.09	0.19	0.02	-0.02	1.00																				
Hf	0.41	0.27	-0.48	-0.35	-0.35	-0.25	0.48	0.50	-0.08	-0.22	-0.46	-0.10	-0.02	-0.21	-0.04	-0.43	-0.40	0.54	-0.22	-0.37	-0.42	0.27	0.17	-0.04	0.63	0.51	-0.14	-0.50	-0.34	0.30	-0.20	1.00																			
Ta	0.31	0.61	-0.49	-0.54	-0.43	-0.29	0.69	0.57	-0.32	-0.16	-0.50	-0.45	-0.19	-0.14	0.42	-0.46	-0.50	0.53	-0.14	-0.49	-0.53	0.45	0.34	-0.10	0.55	0.70	-0.27	-0.52	-0.19	0.63	0.11	0.41	1.00																		
U	0.34	0.64	-0.55	-0.46	-0.43	-0.32	0.73	0.73	-0.39	-0.09	-0.55	-0.38	0.07	-0.19	0.37	-0.53	-0.51	0.70	-0.16	-0.50	-0.58	0.47	0.19	-0.10	0.68	0.74	-0.29	-0.59	-0.26	0.76	0.02	0.46	0.65	1.00																	
La	0.09	0.04	-0.07	0.01	-0.06	-0.12	0.06	0.08	-0.06	-0.03	-0.05	-0.02	-0.02	-0.03	0.27	-0.03	-0.08	0.06	0.07	-0.07	-0.13	0.02	-0.09	0.13	0.05	0.21	-0.02	-0.13	-0.03	0.22	0.12	0.35	0.14	0.21	1.00																
Ce	0.26	0.53	-0.36	-0.42	-0.40	-0.32	0.49	0.40	-0.27	-0.16	-0.36	-0.21	0.06	-0.21	0.56	-0.43	-0.42	0.46	0.04	-0.43	-0.50	0.34	0.16	0.16	0.43	0.71	-0.27	-0.41	-0.22	0.70	0.12	0.41	0.53	0.55	0.47	1.00																									
Pr	0.24	0.55	-0.36	-0.41	-0.37	-0.30	0.48	0.40	-0.25	-0.08	-0.35	-0.19	-0.01	-0.22	0.60	-0.42	-0.42	0.42	0.05	-0.49	-0.52	0.31	0.18	0.20	0.42	0.69	-0.35	-0.43	-0.16	0.72	0.08	0.31	0.51	0.54	0.49	0.90	1.00																								
Nd	0.23	0.53	-0.31	-0.35	-0.35	-0.30	0.45	0.36	-0.20	-0.10	-0.34	-0.18	0.05	-0.23	0.59	-0.37	-0.34	0.39	0.08	-0.46	-0.47	0.26	0.17	0.18	0.39	0.66	-0.33	-0.39	-0.13	0.68	0.18	0.31	0.50	0.52	0.51	0.93	0.97	1.00																							
Eu	0.11	0.42	-0.02	-0.06	-0.24	-0.24	0.37	0.08	0.27	0.01	-0.25	-0.16	0.04	0.06	0.29	-0.10	0.02	0.25	0.02	-0.28	-0.09	-0.09	0.33	-0.13	0.30	0.36	-0.27	-0.08	0.02	0.47	-0.02	0.24	0.29	0.30	0.33	0.45	0.48	0.51	1.00																						
Sm	0.36	0.67	-0.44	-0.50	-0.51	-0.39	0.65	0.51	-0.23	-0.15	-0.51	-0.24	0.00	-0.10	0.52	-0.54	-0.49	0.62	-0.06	-0.55	-0.57	0.38	0.22	0.05	0.61	0.82	-0.39	-0.53	-0.29	0.81	-0.06	0.41	0.60	0.66	0.34	0.85	0.86	0.85	0.61	1.00																					
Tb	0.24	0.34	-0.18	-0.18	-0.33	-0.25	0.37	0.27	0.01	-0.16	-0.31	-0.14	0.16	-0.22	0.28	-0.26	-0.14	0.45	-0.06	-0.34	-0.25	0.16	0.00	0.00	0.39	0.53	-0.23	-0.22	-0.10	0.44	0.31	0.29	0.35	0.42	0.36	0.76	0.66	0.79	0.41	0.64	1.00																				
Gd	0.34	0.56	-0.33	-0.35	-0.46	-0.37	0.57	0.47	-0.09	-0.10	-0.48	-0.26	0.00	-0.26	0.46	-0.43	-0.38	0.65	-0.11	-0.53	-0.46	0.28	0.08	0.06	0.59	0.77	-0.37	-0.43	-0.22	0.70	-0.01	0.46	0.58	0.68	0.42	0.79	0.81	0.81	0.59	0.91	0.71	1.00																			
Dy	0.38	0.51	-0.35	-0.37	-0.48	-0.35	0.61	0.50	-0.04	-0.14	-0.53	-0.28	0.00	-0.28	0.30	-0.45	-0.39	0.75	-0.26	-0.53	-0.43	0.29	0.00	-0.05	0.68	0.80	-0.35	-0.45	-0.27	0.62	-0.09	0.48	0.54	0.67	0.25	0.65	0.65	0.63	0.45	0.84	0.65	0.92	1.00																		
Ho	0.37	0.49	-0.33	-0.34	-0.45	-0.34	0.60	0.47	-0.02	-0.18	-0.51	-0.29	0.03	-0.28	0.27	-0.42	-0.33	0.73	-0.24	-0.51	-0.41	0.24	0.02	-0.09	0.66	0.77	-0.33	-0.42	-0.23	0.59	0.05	0.45	0.52	0.64	0.23	0.71	0.66	0.70	0.43	0.80	0.83	0.87	0.93	1.00																	
Er	0.43	0.53	-0.41	-0.41	-0.51	-0.37	0.66	0.57	-0.06	-0.21	-0.60	-0.32	0.01	-0.26	0.22	-0.51	-0.42	0.82	-0.30	-0.54	-0.48	0.32	0.04	-0.14	0.76	0.81	-0.33	-0.50	-0.32	0.60	-0.06	0.49	0.55	0.69	0.17	0.61	0.57	0.57	0.39	0.77	0.66	0.85	0.95	0.95	1.00																
Tm	0.42	0.56	-0.48	-0.46	-0.50	-0.35	0.69	0.59	-0.13	-0.21	-0.59	-0.34	0.02	-0.26	0.21	-0.53	-0.49	0.87	-0.34	-0.56	-0.53	0.32	0.08	-0.14	0.79	0.84	-0.34	-0.55	-0.37	0.64	-0.07	0.52	0.60	0.74	0.17	0.59	0.57	0.56	0.39	0.78	0.62	0.84	0.94	0.92	0.96	1.00															
Yb	0.47	0.59	-0.53	-0.52	-0.55	-0.39	0.74	0.68	-0.16	-0.23	-0.65	-0.35	-0.02	-0.24	0.22	-0.59	-0.53	0.88	-0.34	-0.58	-0.57	0.41	0.10	-0.15	0.83	0.88	-0.34	-0.60	-0.41	0.65	-0.06	0.55	0.63	0.75	0.17	0.60	0.58	0.56	0.37	0.78	0.59	0.83	0.92	0.90	0.96	0.97	1.00														
Lu	0.48	0.58	-0.54	-0.52	-0.57	-0.39	0.74	0.67	-0.15	-0.22	-0.64	-0.32	-0.03	-0.21	0.18	-0.61	-0.53	0.90	-0.36	-0.58	-0.57	0.41	0.11	-0.18	0.86	0.88	-0.34	-0.58	-0.40	0.63	-0.11	0.58	0.61	0.74	0.15	0.59	0.56	0.54	0.35	0.76	0.58	0.81	0.91	0.88	0.95	0.96	0.98	1.00													
Cd	-0.08	-0.04	0.01	-0.04	0.05	0.11	-0.06	-0.07	-0.03	0.13	0.06	-0.03	-0.23	0.29	-0.05	0.08	0.06	-0.07	-0.03	-0.01	0.02	-0.01	-0.02	-0.01	-0.06	-0.09	-0.07	0.04	0.19	-0.08	0.07	-0.20	0.09	-0.06	-0.13	-0.09	-0.07	-0.08	-0.17	-0.06	-0.14	-0.12	-0.09	-0.10	-0.11	-0.09	-0.11	-0.07	1.00												
Au (ppm	-0.02	0.06	0.13	0.01	-0.03	-0.07	0.08	-0.04	0.19	-0.06	-0.01	-0.20	-0.14	-0.02	0.03	0.09	0.13	0.02	-0.11	-0.03	0.06	-0.10	0.10	-0.11	0.06	0.03	-0.05	0.10	0.04	-0.04	0.05	0.07	0.10	0.02	0.18	-0.02	0.02	0.03	0.10	0.02	0.02	0.10	0.04	0.01	-0.01	0.03	0.03	0.03	-0.08	1.00											
Se ppm	0.21	0.19	-0.09	-0.20	-0.10	-0.21	0.19	0.06	-0.12	-0.11	-0.24	-0.15	0.16	-0.08	0.18	-0.15	-0.19	0.09	0.07	-0.15	-0.19	0.05	-0.05	-0.06	0.13	0.15	-0.02	-0.16	-0.13	0.23	-0.04	0.07	0.17	0.17	0.10	0.19	0.23	0.20	0.00	0.21	0.10	0.19	0.18	0.15	0.18	0.18	0.17	0.15	0.26	0.01	1.00										
Li	-0.01	-0.30	0.22	0.20	0.29	-0.10	-0.41	-0.15	-0.09	-0.02	0.16	0.43	-0.09	0.76	-0.04	0.18	0.23	-0.27	-0.03	0.38	0.23	0.07	-0.26	0.16	-0.34	-0.34	0.14	0.19	0.01	-0.17	0.25	-0.32	-0.24	-0.27	-0.06	-0.25	-0.25	-0.24	-0.08	-0.20	-0.28	-0.34	-0.37	-0.38	-0.39	-0.40	-0.38	-0.37	0.16	-0.07	-0.19	1.00									
Mo	0.23	0.14	-0.05	0.06	-0.03	-0.29	0.08	0.36	-0.20	0.05	-0.28	-0.04	0.07	0.32	0.06	-0.16	0.05	0.16	-0.10	-0.03	-0.09	0.21	-0.20	-0.04	0.19	0.09	-0.06	-0.10	-0.14	0.27	0.23	-0.06	0.05	0.40	0.02	0.00	-0.01	0.00	-0.01	0.06	-0.01	0.03	0.05	0.07	0.11	0.10	0.13	0.14	0.19	-0.04	0.07	0.42	1.00								
In	-0.30	-0.15	0.65	0.55	0.32	0.07	-0.41	-0.42	0.31	0.18	0.26	0.12	-0.03	0.10	0.16	0.49	0.67	-0.42	0.28	0.28	0.51	-0.42	-0.06	0.15	-0.42	-0.36	0.08	0.56	0.31	-0.12	0.27	-0.36	-0.25	-0.25	0.01	-0.15	-0.10	-0.06	0.14	-0.19	-0.10	-0.14	-0.20	-0.20	-0.25	-0.32	-0.35	-0.35	0.10	0.01	-0.23	0.31	0.31	1.00							
Sb	-0.22	-0.57	0.51	0.66	0.46	0.09	-0.78	-0.46	0.22	0.12	0.47	0.36	0.17	0.21	-0.17	0.46	0.57	-0.50	0.24	0.48	0.48	-0.32	-0.53	0.30	-0.59	-0.60	0.22	0.52	0.20	-0.46	0.28	-0.32	-0.57	-0.45	0.12	-0.32	-0.33	-0.27	-0.26	-0.49	-0.17	-0.43	-0.48	-0.43	-0.51	-0.55	-0.59	-0.58	0.00	-0.06	-0.16	0.46	0.21	0.44	1.00						
Te	0.36	0.41	-0.37	-0.35	-0.40	-0.25	0.47	0.42	-0.05	-0.17	-0.48	-0.29	-0.07	-0.08	0.01	-0.44	-0.29	0.41	-0.16	-0.37	-0.39	0.19	0.28	-0.13	0.51	0.40	-0.24	-0.39	-0.31	0.28	0.05	0.34	0.36	0.31	0.05	0.34	0.35	0.35	0.31	0.46	0.32	0.43	0.44	0.43	0.44	0.44	0.49	0.48	0.02	0.13	0.12	-0.19	0.01	-0.07	-0.39	1.00					
Cs	0.01	-0.17	-0.08	0.10	0.07	-0.04	-0.33	0.04	-0.17	0.08	0.19	0.26	0.02	0.14	0.04	-0.06	-0.05	-0.09	0.23	0.09	-0.09	0.17	-0.21	0.40	-0.18	-0.19	-0.05	-0.05	0.05	-0.04	0.03	-0.07	-0.15	-0.13	0.07	-0.02	0.00	-0.02	-0.22	-0.10	-0.06	-0.11	-0.16	-0.17	-0.17	-0.19	-0.18	-0.17	0.01	-0.19	-0.11	0.31	0.04	0.02	0.48	-0.18	1.00				
W	0.04	0.11	-0.06	0.07	-0.07	-0.06	0.13	0.19	0.05	-0.03	-0.10	-0.09	-0.26	0.07	-0.07	-0.01	0.00	0.25	-0.27	-0.11	-0.05	-0.01	-0.11	-0.15	0.22	0.10	-0.10	-0.11	0.01	0.04	0.02	-0.07	0.12	0.14	-0.15	-0.02	-0.01	-0.02	0.04	0.03	-0.01	0.07	0.13	0.16	0.20	0.17	0.21	0.21	0.11	-0.09	-0.22	0.04	0.27	0.00	-0.07	-0.01	-0.03	1.00			
Tl	0.51	0.53	-0.72	-0.66	-0.58	-0.38	0.63	0.79	-0.43	-0.18	-0.57	-0.19	0.01	-0.14	0.24	-0.76	-0.70	0.73	-0.12	-0.58	-0.70	0.84	0.18	0.08	0.72	0.78	-0.36	-0.65	-0.44	0.61	-0.08	0.49	0.61	0.68	0.03	0.53	0.49	0.45	0.05	0.60	0.37	0.56	0.59	0.56	0.64	0.66	0.72	0.74	-0.06	-0.06	0.09	-0.24	0.13	-0.46	-0.50	0.35	0.08	0.04	1.00		
Bi	0.12	0.24	-0.09	-0.04	-0.05	-0.12	0.15	0.09	-0.14	-0.05	-0.22	-0.07	0.02	0.01	0.10	-0.09	0.00	-0.12	0.30	-0.08	-0.15	0.00	0.27	-0.13	0.01	-0.01	-0.03	-0.10	-0.11	0.14	0.13	0.01	0.00	0.04	0.07	-0.04	-0.02	0.00	0.11	-0.02	-0.04	-0.05	-0.07	-0.04	-0.04	-0.03	0.00	-0.02	0.04	-0.09	0.04	0.06	0.32	0.27	-0.03	0.10	0.00	-0.05	-0.04	1.00	
Hg	0.03	-0.14	0.16	0.26	0.06	-0.06	-0.18	-0.08	0.15	0.19	0.03	0.23	0.13	0.15	-0.06	0.08	0.20	-0.13	0.12	0.13	0.21	-0.06	-0.12	0.01	-0.13	-0.16	0.01	0.14	0.14	-0.14	-0.05	-0.03	-0.21	-0.11	0.10	-0.16	-0.15	-0.13	0.09	-0.09	-0.09	-0.09	-0.07	-0.10	-0.07	-0.13	-0.11	-0.13	-0.08	-0.06	0.14	0.19	0.09	0.09	0.20	-0.08	0.01	-0.02	-0.15	0.05	1.00

7.2 SURFACE AND SUBSRFACE SOIL CHEMISTRY

7.2.1 Major oxides:

Silicon Dioxide (SiO_2): In the soil samples, SiO_2 values in the area vary from 28.96 to 73.47 % with average value of 56.23 %. Only 04 samples have SiO_2 values above the crustal abundance of 66.6% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). Moderate concentrations are observed in Paiguttavaripalli situated in east of Mallepalle and Gottru and nallacheruvupalle areas. These moderate concentrations could have resulted due to the presence of grey hornblende granite/ Gneiss of PGC-II group of rocks in the south and shale/ quartzite of Cuddapah group of rocks (Fig7.7). The SiO_2 content in the regolith samples varies from 32.4 to 70.12 % and C- Horizon varies from 29.77 to 66.33 %. (Table.7.3). The Bar graph (Fig.7.8) of soil profiles shows over all the profiles SiO_2 rich in regolith and low in C-horizon, it states that the decreased with depth and SiO_2 strongly resists weathering because it is mainly contained in quartz minerals. In health hazard point of view while breathing silica dust may case the effect of Silicosis, risk of lung infections, chronic bronchitis, and several autoimmune diseases.

Aluminium Oxide (Al_2O_3): In the soil samples, Al_2O_3 values in the area vary from 9.24 to 19.83 % with average value of 13.79 %. About 26 % of samples have Al_2O_3 values above the crustal abundance of 15.4% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). High concentration of $Al_2O_3 > 20$ % is observed in and around Lakkasamudram, Udumulakurthi, Siddareddy palli, peddannavaripalli and kondagattu palli areas over the PGC-II group of rocks (Fig.7.7). The Al_2O_3 content in the regolith samples varies from 7.84 to 21.09 % and C-Horizon varies from 4.61 to 28.37 % (Table 7.3). The Bar graph (Fig.7.8) of soil profiles in PGC-II and Cuddapah group is Al_2O_3 is more concentrated in c-horizonon compare with to the Regolith as it is immobile and less and weathered prone and few regolith samples is greater than that of C Horizon and vice versa. It indicates that the proportion of alumina to alkalis in some the samples is more in the R than that of C-Horizon and otherwise, despite the fact that both the horizons consists of products of weathering. Oral exposure to aluminium is usually not harmful. Some studies show that people exposed to high levels of aluminium may develop Alzheimer's disease

Iron Oxide (Fe_2O_3): In the soil samples Fe_2O_3 concentration in the area varies from 2.75 to 12.34 % with average value of 6.78 %. About 80 % of samples have Fe_2O_3 values above the crustal abundance of 5.04% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). High concentrations are observed in the Puttakinamma, Boggudupalli, Vempampeta, Bakkanagari palli, Ipatla areas over the Cuddapah group and PGC-II group of rocks (Fig 7.7). The Fe_2O_3

content in the regolith samples varies from 2.40 to 15.39 % and C- Horizon varies from 3.27 to 16.58 % (Table 7.3). The Bar graph (Fig.7.8) of soil profiles in Cuddapah group shows Fe_2O_3 is more concentrated in regolith with compare to the C-horizon underlined in basic rock and Shale. In Peninsular gneissic complex-II group (PGC-II) in one samples of regolith is greater than that of C Horizon and vice versa. Exposure to Iron Oxide fumes can cause metal fume fever. This is a flu-like illness with symptoms of metallic taste, fever and chills, aches, chest tightness and cough.

Magnesium Oxide (MgO): Mgo values in soil samples vary from 0.32 to 8.18 % with average value of 2.44 %. About 45 % of samples have MgO values above the crustal abundance of 2.48% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). High concentrations are observed in the Vempalli, bakkanagari palli, Pulivendula, Ambakapalli areas over the Dolomite in Cuddapah super group of rocks (Fig 7.7). The MgO content in the regolith samples varies from 0.41 to 7.99 % and C- Horizon varies from 0.55 to 13.22 % (Table 7.3). The Bar graph (Fig.7.8) of all soil profiles shows Regolith samples are in some samples is greater than that of C Horizon and vice versa (Table.7.3)

Manganese Oxide (MnO): Mno values in soil samples vary from 0.04 to 0.23 % with average value of 0.11 %. About 54 % of samples have MnO values above the crustal abundance of 0.1% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). Low concentrations are observed in the Peddajuttur, N.Palagiri and vempalli areas over the Cuddapah super group of rocks (Fig 7.7). The MnO content in the regolith samples varies from 0.04 0.21 % and C- Horizon varies from 0.05 to 0.28% (Table 7.3). The Bar graph (Fig.7.8) of all soil profiles shows in some regolith samples is greater than that of C Horizon and vice versa.

Calcium Oxide (CaO): CaO values in soil samples vary from 0.42 to 22.38 % with average value of 3.57 %. About 38.3 % of samples have CaO values above the crustal abundance of 3.59 % (R.L. Rudnick and S. Gao, 2004) (Table 7.1). Moderate concentrations are observed in the Vemula areas over the Cuddapah super group of rocks (Fig 7.7). The CaO content in the regolith samples varies from 0.64 to 15.34 % and C- Horizon varies from 0.48 to 22.37 % (Table 7.3). The Bar graph (Fig.7.8) of all soil profiles shows that the concentration of CaO is more in the C horizon in comparison to the regolith, this is due to the removal of CaO in solution on the surface layers.

Sodium Oxide (Na_2O): Na_2O values in soil samples varies from 0.05 to 3.53 % with average value of 0.90 %. No significant concentrations are observed (Fig 7.7). The Na_2O content in the regolith samples varies from 0.15 to 2.56 % and C- Horizon varies from 0.11 to

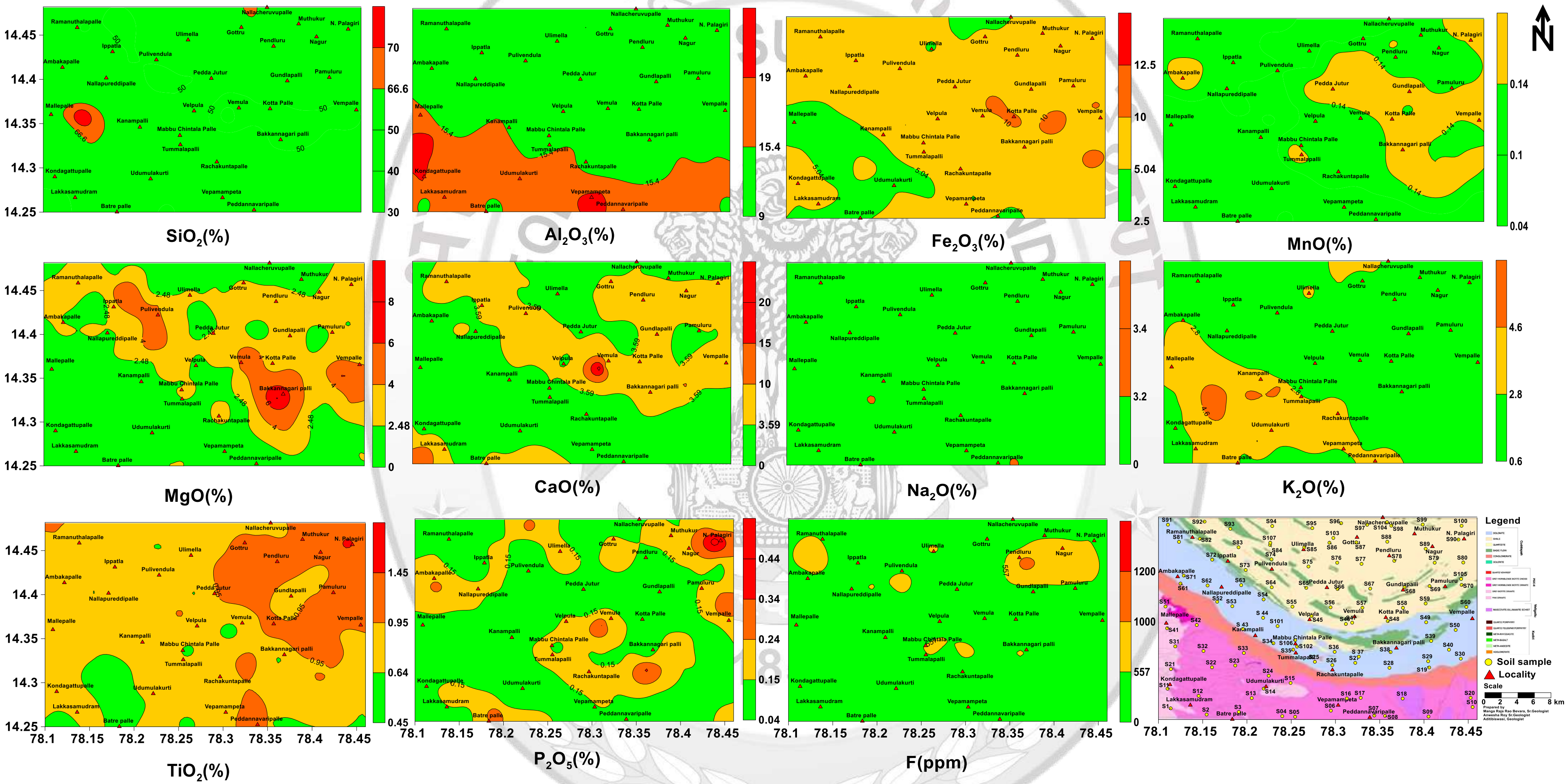
1.75 % (Table 7.3). The Bar graph (Fig.7.8) shows, all the soil profiles having regolith samples are greater than that of C Horizon and vice versa.

Potassium Oxide (K_2O): K_2O values in soil samples vary from 0.55 to 5.38 % with average value of 2.18 %. About 27 % of samples have K_2O values above the crustal abundance of 2.80% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). High concentrations are observed in the Lakkasamudram, Udumulakurthi, Siddareddy palli, peddannavaripalli and kondagattu palli areas over the PGC-II group of rocks (Fig.7.7). The K_2O content in the regolith samples varies from 0.43 to 5.19 % and C- Horizon varies from 0.21 to 3.98 % (Table 7.3).K_2O having positive correlation with SiO_2, Al_2O_3 and Na_2O (Table. 7.2). The Bar graph (Fig.7.8) of all soil profiles shows some regolith samples are greater than that of C Horizon and vice versa. Potassium is most commonly used for treating and preventing low potassium levels, treating high blood pressure, and preventing stroke. An increased potassium intake lowers urinary calcium excretion and plays an important role in the management of hypercalciuria and kidney stones and is likely to decrease the risk of osteoporosis

Titanium Oxide (TiO_2): TiO_2 values in soil samples vary from 0.4 to 2.37 % with average value of 0.98 %. About 90.5 % of samples have TiO_2 values above the crustal abundance of 0.64% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). High concentrations are observed in the N. Palgiri area over the Cuddapah super group of rocks (Fig.7.7) The TiO_2 content in the regolith samples varies from 0.39 to 1.54 % and C- Horizon varies from 0.28 to 0.93 % (Table 7.3). The Bar graph (Fig.7.8) of soil profiles in Cuddapah super group of rocks shows regolith samples is greater than that of C Horizon and some samples is regolith samples are greater than that of C Horizon vice versa in profiles collected from Peninsular Gneissic –II. Titanium dioxide (TiO_2) is a natural oxide of the element titanium with low toxicity, and negligible biological effects

Phosphorus Oxide (P_2O_5): P_2O_5 values in soil samples vary from 0.05 to 0.51 % with average value of 0.14 %. About 32 % of samples have P_2O_5 values above the crustal abundance of 0.15% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). Low to moderate concentrations are observed in the N.Palagiri areas overlied on the Cuddapah super group of rocks (Fig.7.7). The P_2O_5 content in the regolith samples varies from 0.06 to 0.18 % and C-Horizon varies from 0.05 to 0.21 % (Table 7.3). The Bar graph (Fig.7.8) of all soil profiles shows some regolith samples are greater than that of C Horizon and vice versa.

Fig. 7.7 Spatial distribution pattern of Major Oxides (%) and Fluoride (ppm) in soil samples of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



SiO_2(%)

Al_2O_3(%)

Fe_2O_3(%)

MnO(%)

MgO(%)

CaO(%)

Na_2O(%)

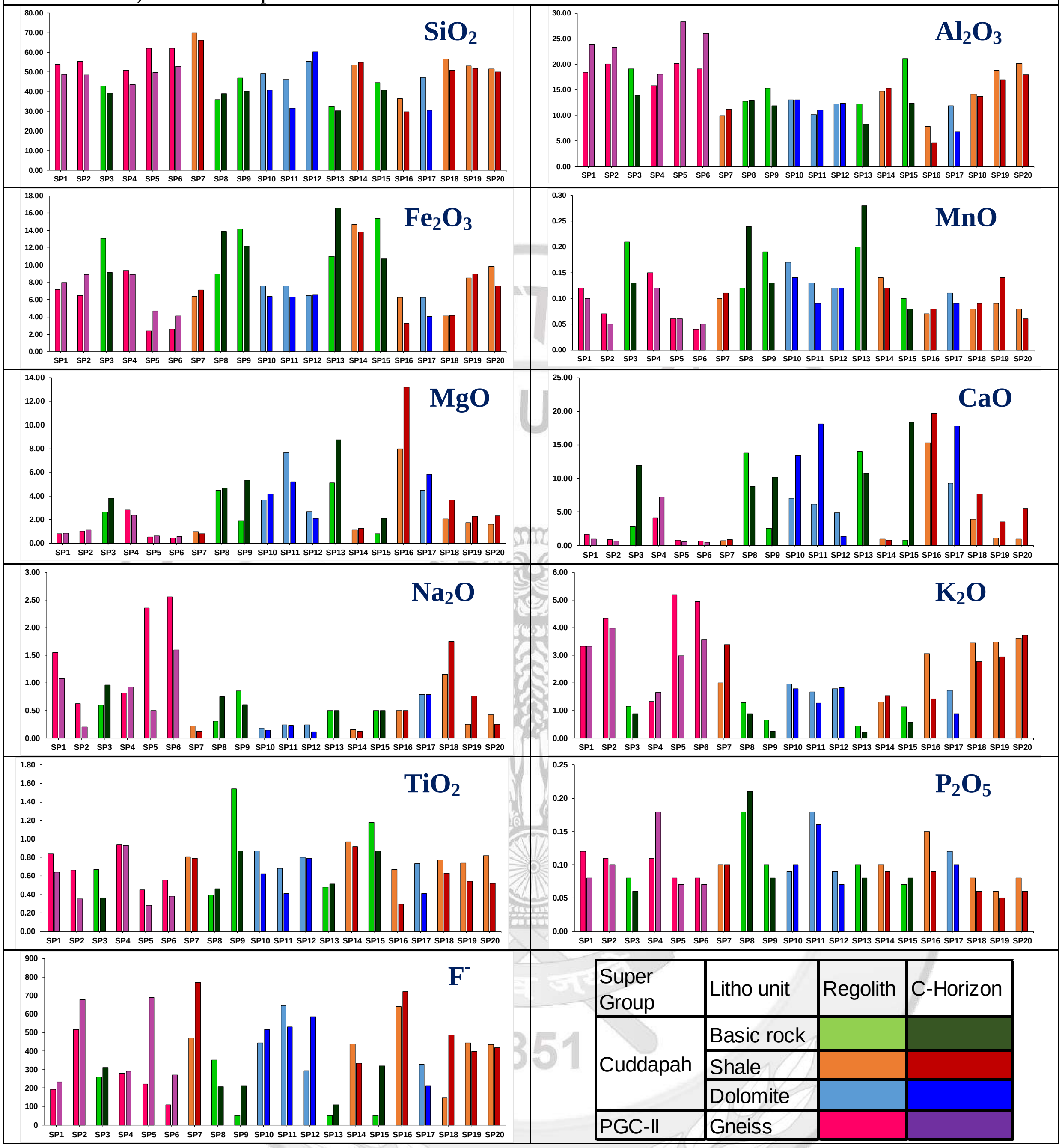
K_2O(%)

TiO_2(%)

P_2O_5(%)

F(ppm)

Fig:7.8 Bar graph showing major oxides(%) and Fluoride (ppm) concentrations in soil profile samples (Regolith & C-Horizon) in Tummalapalli area.



Super Group	Litho unit	Regolith	C-Horizon
Cuddapah	Basic rock	🟩	🟩
	Shale	🟧	🟥
	Dolomite	🟦	🟦
PGC-II	Gneiss	🟥	🟪

7.2.2 RARE EARTH ELEMENTS:

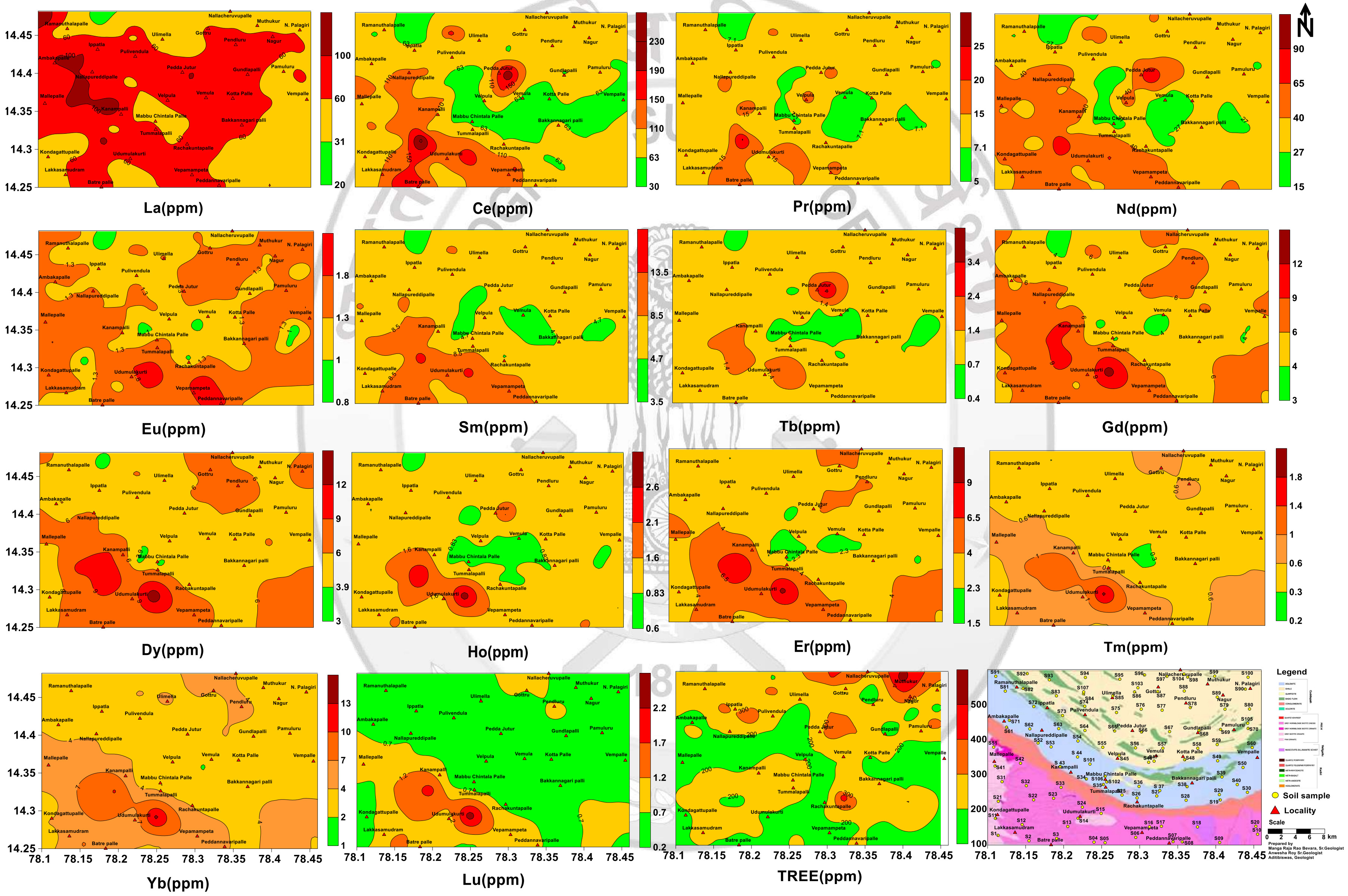
In LREE elements like Lanthanum (La) values in soil samples varies from are 22.51 to 122.36 ppm with mean of 63.78. Cerium (Ce) values varies from 41.84 to 244.94 ppm with mean value being 86.11 ppm. Praseodymium (Pr) values varies from 4.90 to 26.04 ppm with mean of 10.03 ppm. Neodymium (Nd) values varies from 17.95 to 90.42 ppm with mean of 36.32 ppm. Europium (Eu) values are avaries from 0.82 to 2.30 ppm with mean of 1.35 ppm. Samarium (Sm) shows 3.61 to 15.75 ppm with mean of 6.71 ppm.

In HREE elements are Gadolinium (Gd) shows values varies from 3.20 to 13.45 ppm with mean of 5.88 ppm. Terbium (Tb) values varies from 0.50 to 3.69 ppm with mean of 0.97 ppm. Dysprosium (Dy) shows values varies from 3.20 to 14.13 ppm with mean of 5.79 ppm. Holmium (Ho) values varies from 0.65 to 2.86 ppm with mean of 1.13 ppm. Erbium (Er) values shows 1.78 to 9.75 ppm with mean of 3.55 ppm. Thulium (Tm) values varies from 0.28 to 1.90 ppm with mean of 0.57 ppm. Ytterbium (Yb) values varies from 1.86 to 13.84 ppm with mean of 3.94 ppm. Lutetium (Lu) values varies from 0.27 to 2.50 ppm with mean of 0.66 ppm.

In Total rare earth elements content in soil samples varies from 107 to 537 ppm, higher values are observed for the HREE elements ratherthan LREE. 92% of samples contains LREE high and 98% of samples contains HREE values above the crustal abundance of 0.1% (R.L. Rudnick and S. Gao, 2004) (Table 7.1). They show similar distribution pattern. Higher values of all these elements observed in and around Somalapalli and Udumulakurthi areas these areas are underlined by the grey hornblende biotite granite/ gneiss of PGC-II group of rocks in south western part of thee study area (Fig 7.9).

In the Bar graph (Table.7.10) (Fig.7.9) shows of REE (LREE & HREE) pattern have higher concentration in C- horizon and low concentarion on regolith in Peninsular gneissic-II group (PG-II), it may tell to C-Horizon close to the bedrock whereas less concentration in regolith which is more prone to erosion. In Cuddapah super group of rocks is LREE and HREE is more concentrated in Regolith in compare with C-horizon. and, REE pattern in regolith samples are in some samples is greater than that of C Horizon and vice versa. This distribution reveals that high weathering and rainfall leads to the removal of REE from top soil which shows the mobile nature. In Human health point of view Cerium (Ce) can be threat to liver when accumulates in human body. Soluble Praseodymium, Neodymium, Samarium, Terbium, Gadolinium and Hafnium salts are skin and eye irritants. La, Ce and Nd form compounds that are very resistant to weathering and have high resistance. Thus, they get enriched in the regolith. In above data it has been observed that there is no significant elemental concentration in the regolith and C-horizon samples, which are commonly higher in granitic country and does not have direct effect on human health.

Fig. 7.9 Spatial distribution pattern of Rare earth elements (ppm) in soil samples of the study area, Y.S.R Kadapa and Ananthapur Districts, Andhra Pradesh



La(ppm) Ce(ppm) Pr(ppm) Nd(ppm)

Eu(ppm) Sm(ppm) Tb(ppm) Gd(ppm)

Dy(ppm) Ho(ppm) Er(ppm) Tm(ppm)

Yb(ppm) Lu(ppm) TREE(ppm)

Fig:7.10 Bar graph showing Rare eaarth elements (ppm) concentrations in soil profile samples (Regolith & C-Horizon) in Tummalapalli area.

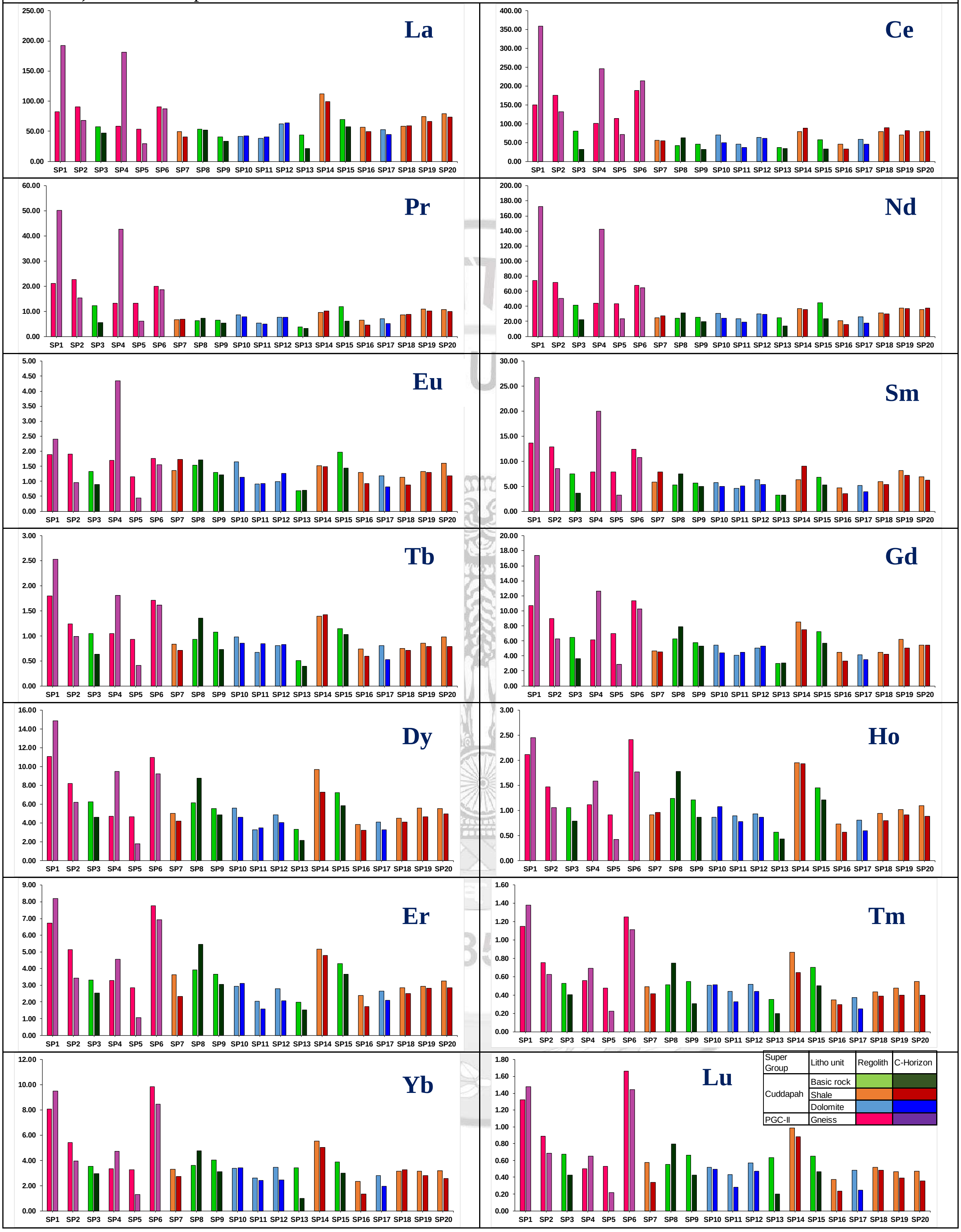
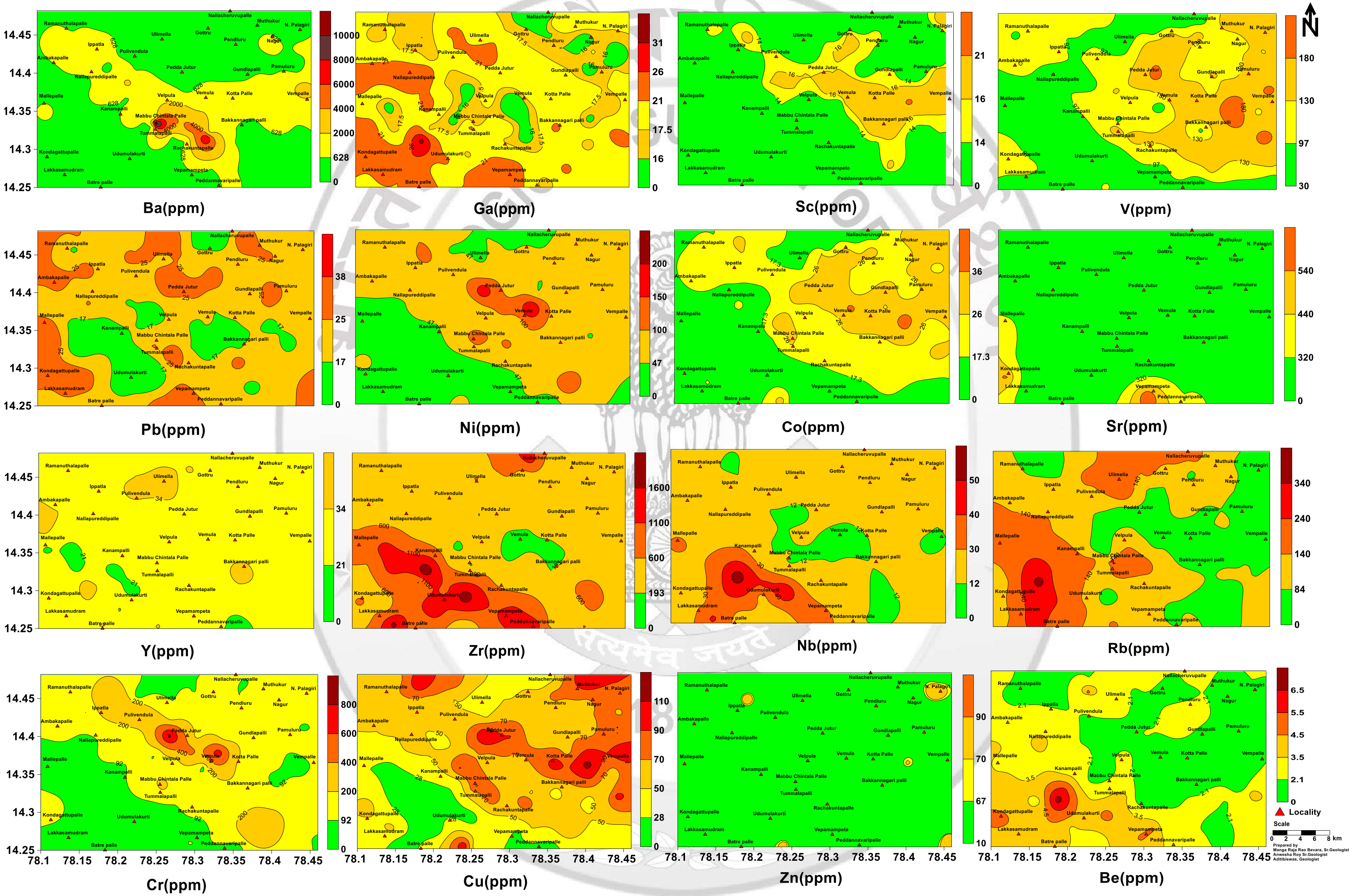


Fig. 7.11 Spatial distribution pattern of Trace elements (ppm) in soil samples of Hutti-Maski area, Raichur District, Karnataka



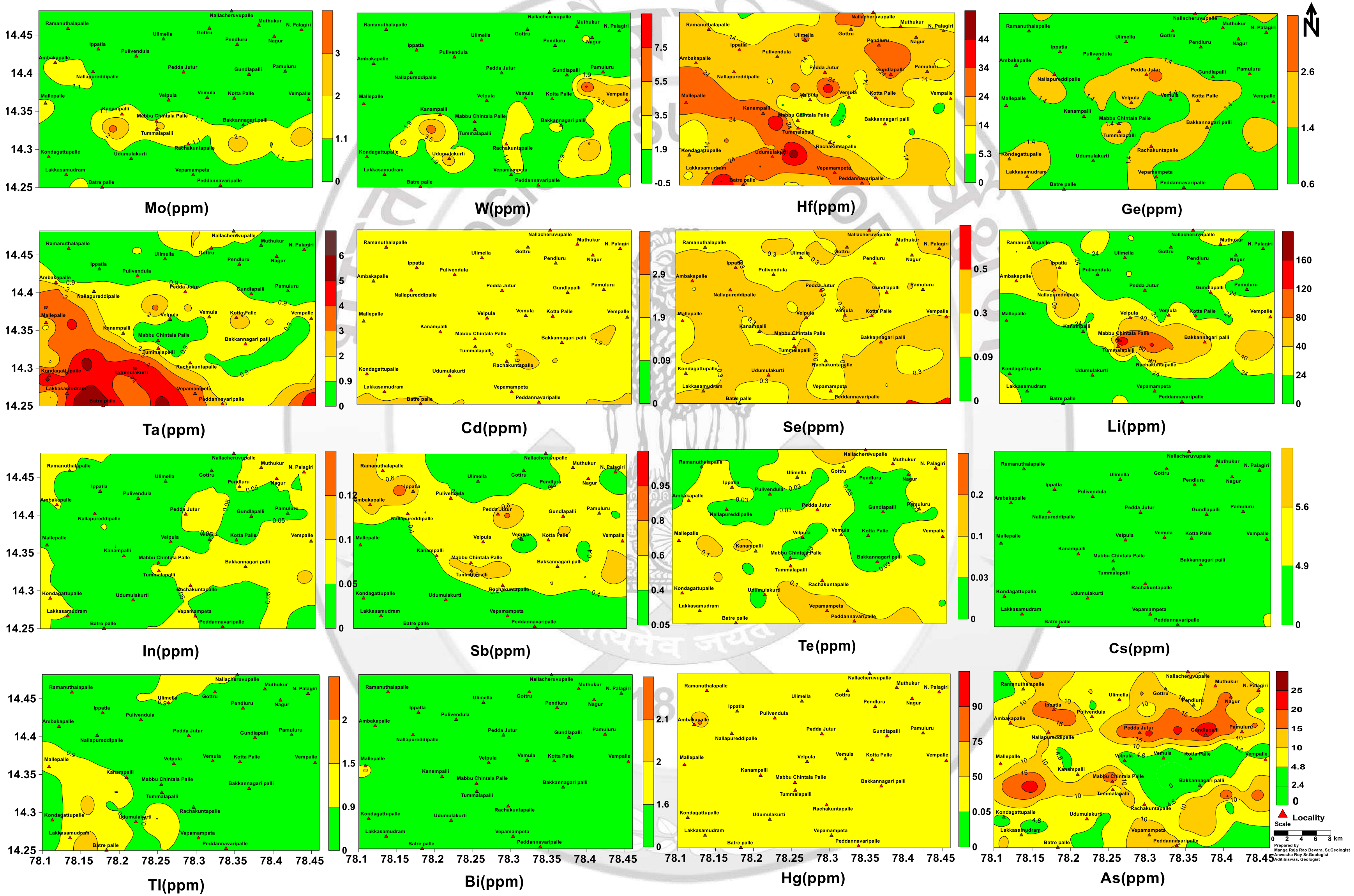
Ba(ppm) Ga(ppm) Sc(ppm) V(ppm)

Pb(ppm) Ni(ppm) Co(ppm) Sr(ppm)

Y(ppm) Zr(ppm) Nb(ppm) Rb(ppm)

Cr(ppm) Cu(ppm) Zn(ppm) Be(ppm)

Fig. 7.12 Spatial distribution pattern of Trace elements (ppm) in soil samples of Hutti-Maski area, Raichur District, Karnataka



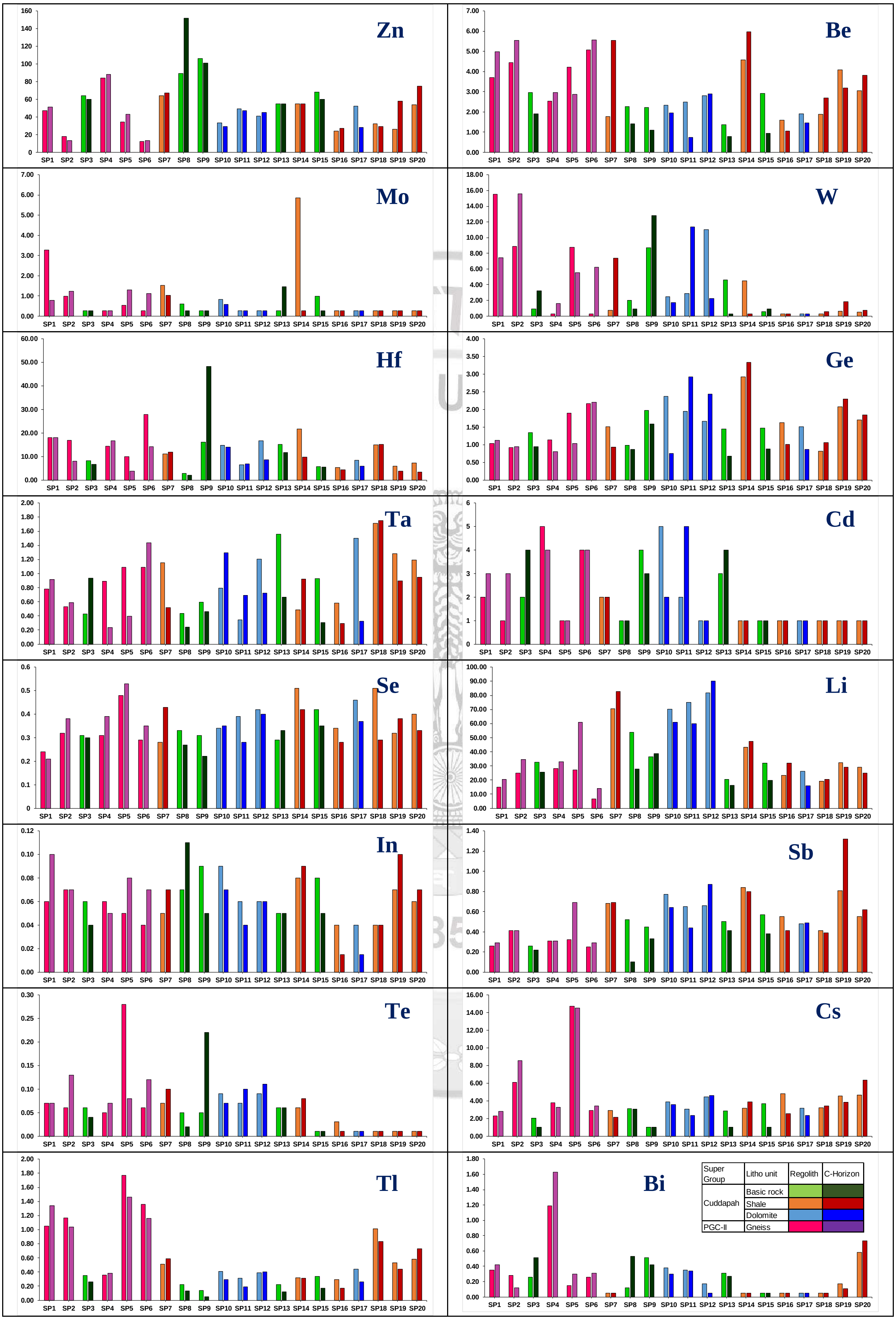
Mo(ppm) W(ppm) Hf(ppm) Ge(ppm)

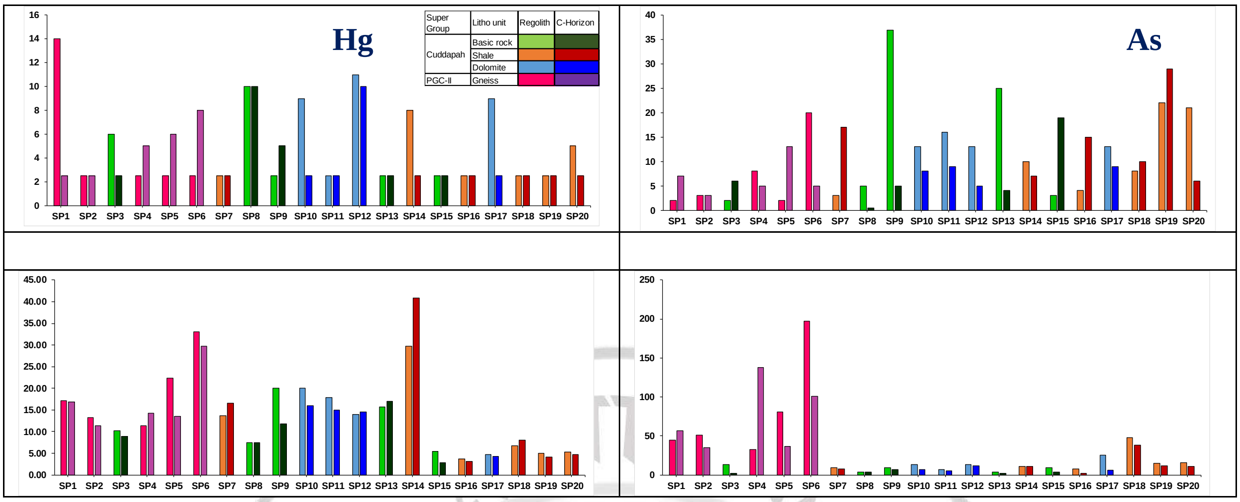
Ta(ppm) Cd(ppm) Se(ppm) Li(ppm)

In(ppm) Sb(ppm) Te(ppm) Cs(ppm)

Tl(ppm) Bi(ppm) Hg(ppm) As(ppm)

Fig:7.13 Bar graph showing Trace elements (ppm) concentrations in soil profile samples (Regolith & C-Horizon) in Tummalapalli area.


Zn
Be
Mo
W
Hf
Ge
Ta
Cd
Se
Li
In
Sb
Te
Cs
Tl
Bi
SP1 SP2 SP3 SP4 SP5 SP6 SP7 SP8 SP9 SP10 SP11 SP12 SP13 SP14 SP15 SP16 SP17 SP18 SP19 SP20
Super Group
Litho unit
Regolith
C-Horizon
Cuddapah
Basic rock
Shale
Dolomite
PGC-II
Gneiss



7.3 Determination of Pollution Indices:

Pollution indices are useful tools for the comprehensive evaluation of the degree of soil contamination. These are of prime importance for assessment of soil quality in terms of heavy metal pollution and to ascertain the sustainability of urban soil. Pollution indices are calculated based on geochemical background values.

Calculation of soil pollution indices requires the assessment of the geochemical background (GB). This term was introduced to distinguish natural concentrations of heavy metals in the soil from abnormal concentrations (**Reimann and Garret 2005**). Hawkes and Webb (1962) were the first who defined geochemical background as ‘the normal abundance of an element in barren earth material.’ According to Matschullat et al (2000), geochemical background is characterized by spatio-temporal changes of the content of heavy metal, which is characteristic for the soil type or region and reflects natural composition of heavy metals. For the present study, calculations of pollution indices were conducted using heavy metal composition from the upper continental crust (UCC) proposed by Rudnick and Gao (2003).

Pollution indices can be categorized as individual indices and complex indices. The following indices were determined for the present work.

7.3.1 Geo-accumulation Index (Igeo):

Geo-accumulation index determines the level of contamination due to a particular contaminant element in soil with respect to a background value of the same element (Muller 1969). I geo is calculated by the formula,

$$\mathbf{I_{geo} = Log_2 [C_{sample}/1.5 \times C_{background}]}$$

where C_{sample} is the measured concentration of a particular metal in sample and $C_{background}$ is the geochemical background value of a particular element in the soil type of an area and and 1.5 constant, allowing for an analysis of the variability of heavy metals as a result of natural processes.

Igeo for different elements classifies the sample into 6 classes mentioned below:

Value of Igeo	Class	Status
<0	Class 0	Un contaminated
0 - 1	Class 1	Uncontaminated to moderately contaminated
1 -2	Class 2	Moderately contaminated
2 - 3	Class 3	Moderate to heavily contaminated
3 - 4	Class 4	Heavily contaminated
4 -5	Class 5	Heavily to extremely contaminated
> 5	Class 6	Extremely contaminated

7.3.2 Contamination Factor (CF):

The CF is the ratio obtained by dividing the concentration of each metal in the soil by the baseline or background value. Contamination factor calculated by the formula,

$$\mathbf{CF = (C_{heavy\ metal} / C_{background})}$$

The contamination levels may be classified based on their intensities on a scale ranging from 1-6 (0 =none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, 6 = very strong) (Muller, 1969).

7.3.3 Enrichment Factor (EF):

Enrichment factor is a measure of the possible impact of anthropogenic activity on the concentration of contaminant elements in soil. For this purpose, the content of metals characterized by low variability of occurrence (LV) in the soil sample and background sample are utilized. Commonly used reference elements for LV are Si, Fe, Al, Ca, Mn etc.for this study Fe was taken reference element.

EF is calculated by the formula: (Sutherland 2000)

$$\mathbf{EF = (\ Cn/LV)\ sample\ /\ (\ GB/LV)\ background}$$

where (Cn /LV) sample content of analyzed heavy metal (Cn) and one of the following metals Fe/Al/Ca/Ti/Sc/ Mn (LV) in the sample and Cn/LV background reference content of the analyzed heavy metal (Cn) and one of the following metals Fe/Al/Ca/Ti/Sc/Mn (LV).

If the value of EF ranges from 0.5 to 1.5, it can be stated that the content of that particular heavy metal in the soil is caused by natural processes. However, if the value of EF exceeds 1.5, there is a possibility that the heavy metal contamination occurred as a result of anthropogenic activities (Elias and Gbadegesin 2011; Zhang and Liu 2002).

7.3.4 Pollution load index (PLI):

The Pollution Load Index (PLI) evaluates the degree to which the soil sediment associated which heavy metal which might impact the micro flora and fauna of soil. For the entire sampling site, PLI has been determined by the calculation of the product of the n CF (Usero et al., 2000)

$PLI = \mathbf{n}\sqrt{(CF_1 \times CF_2 \times CF_3 \times \cdots \times CFn)}$

where, n is the number of metals index provides a simple, comparative means for assessing the level of heavy metal pollution. If the value of PLI is > 1, the soil is considered as polluted. If the value is < 1, the soil is considered as non-polluted.

7.3.5 Spatial distribution of major contaminant elements:

Barium (Ba)

In soil samples, Ba concentration in the area varies from 271 ppm to 11972.8 ppm Spatial distribution map shows overall study area has low to moderate concentration of Ba. The high value zones are observed around the Mabbuchintalapalli, Tummalapalli, UCIL plant and Rachakuntapalli areas these areas are occupied by the Cuddapah group of rocks (Fig.7.11). Ba shows a positive correlation with Li (Table.7.2). About 35.5% of soil samples, near Mabbuchintalapalli, Tummalapalli UCIL tailing pond having high conventrations of Ba values in C-horizon samples have Ba values above the crustal abundance of 628 ppm (R.L. Rudnick and S. Gao, 2004). The Bar graph shows Ba values in regolith samples are high compared to the C-horzon in soil profile from shale and dolomite interclastions in Cuddapah super group of rocks. High value reported in Two nos. of C-horizon samples SP7 (18000 ppm) and 9581 ppm in SP 11 (Table.7.3) (Fig.7.13). Geo-accumulation index (Igeo) map of Ba for soil of study area is given as (Fig. 7.14). Majority of the area is falling under class 0 category, uncontaminated in terms of Ba for soil samples where the high I geo values are obtained bybatrepalli, South of Pulivendula and east of Peddanavari palli settlement areas due to waste disposal. People those live near them may be exposed to harmful levels. Uptake of very large amounts of barium that are water-soluble may cause paralyses and, in some cases, even death.


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Fig:7.14 Geoaccumulation index map of Ba (ppm) showing level of contamination in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

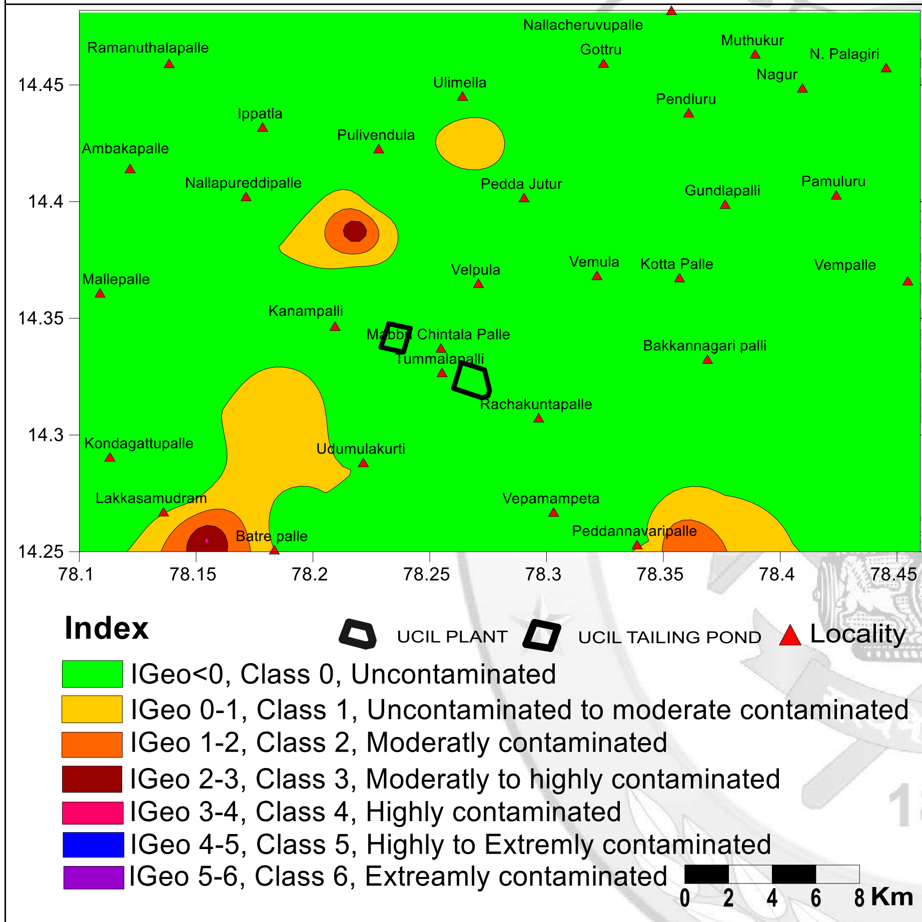


Fig:7.15 Spatial distribution of Enrichment factor map showing Ba (ppm) in Soil and Bar graph of Regolith and C-Horizon in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

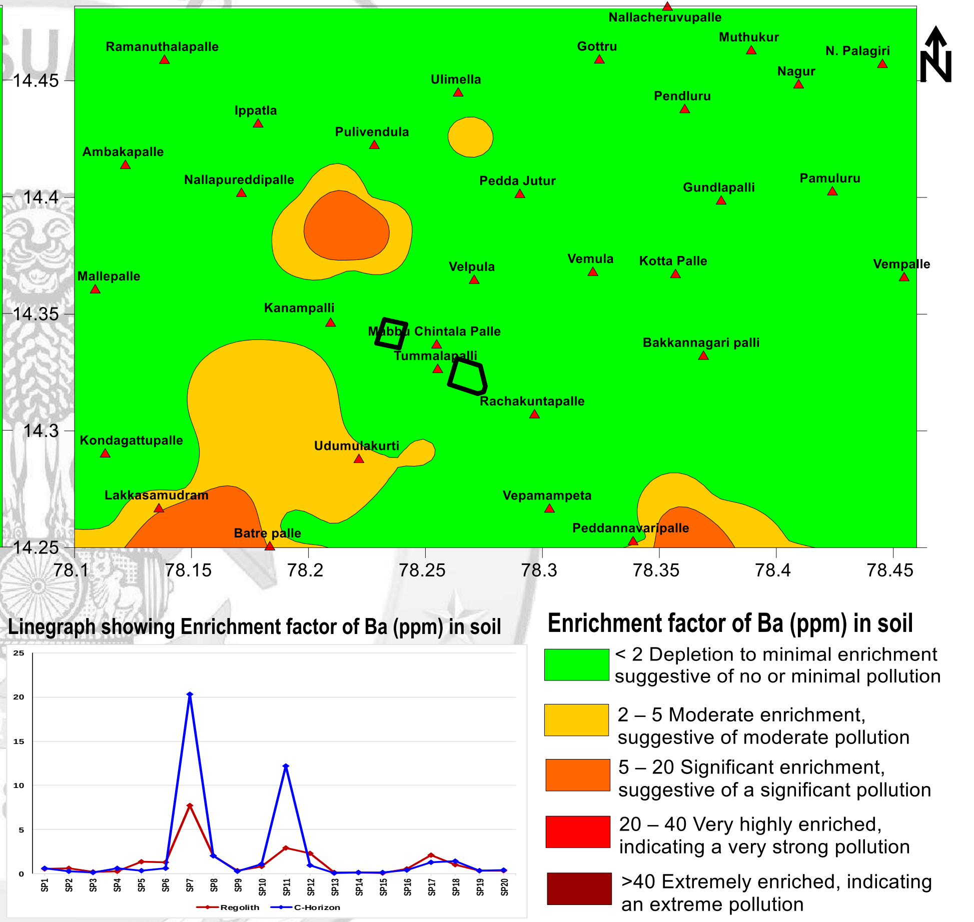
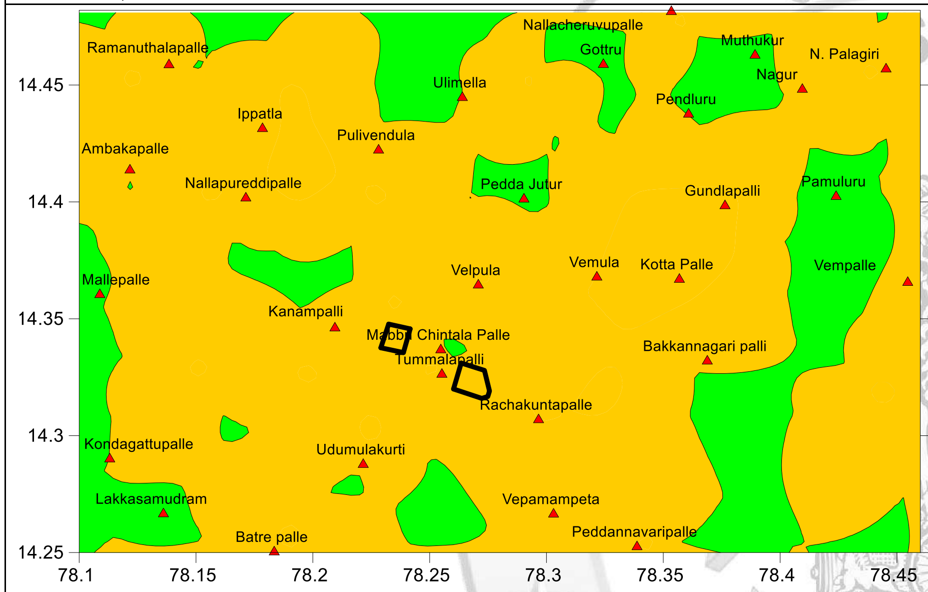
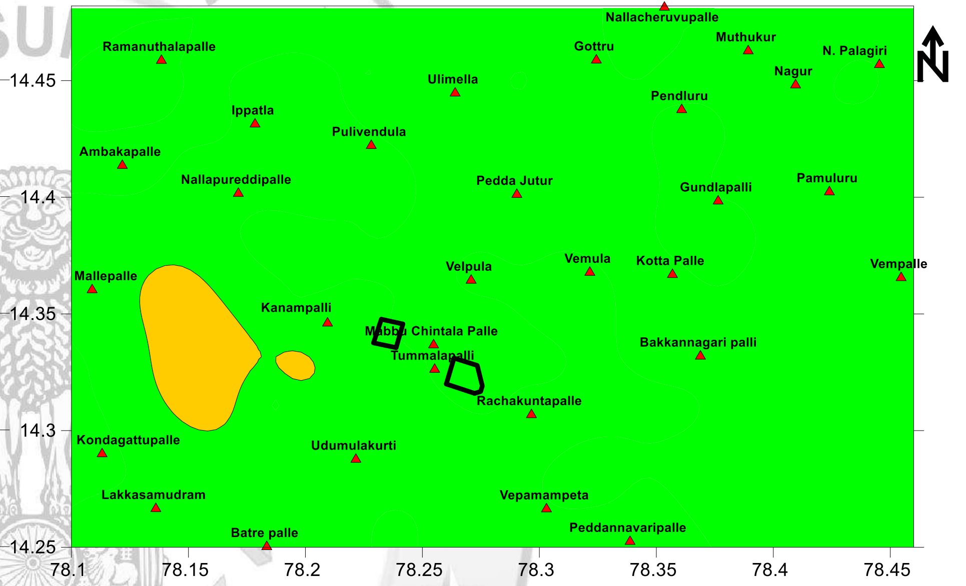


Fig:7.16 Geoaccumulation index map of Pb (ppm) showing level of contamination in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

Fig:7.17 Spatial distribution of Enrichment factor map showing Pb (ppm) in Soil and Bar graph of Regolith and C-Horizon in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh





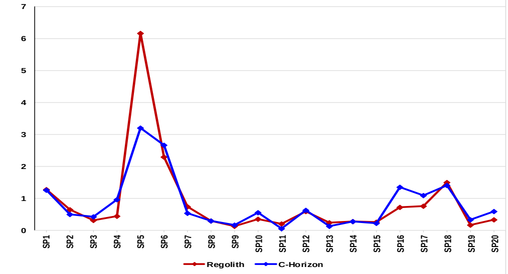
Index

⬠ UCIL PLANT ⬠ UCIL TAILING POND ▲ Locality

- 🟩 IGeo<0, Class 0, Uncontaminated
- 🟨 IGeo 0-1, Class 1, Uncontaminated to moderate contaminated
- 🟧 IGeo 1-2, Class 2, Moderatly contaminated
- 🟫 IGeo 2-3, Class 3, Moderatly to highly contaminated
- 🟥 IGeo 3-4, Class 4, Highly contaminated
- 🟦 IGeo 4-5, Class 5, Highly to Extremly contaminated
- 🟪 IGeo 5-6, Class 6, Extreamly contaminated

0 2 4 6 8 Km

Linegraph showing Enrichment factor of Pb (ppm) in soil



Enrichment factor of Pb (ppm) in soil

- 🟩 < 2 Depletion to minimal enrichment suggestive of no or minimal pollution
- 🟨 2 – 5 Moderate enrichment, suggestive of moderate pollution
- 🟧 5 – 20 Significant enrichment, suggestive of a significant pollution
- 🟥 20 – 40 Very highly enriched, indicating a very strong pollution
- 🟫 >40 Extremely enriched, indicating an extreme pollution

Fig:7.18 Geoaccumulation index map of Ni (ppm) showing level of contamination in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

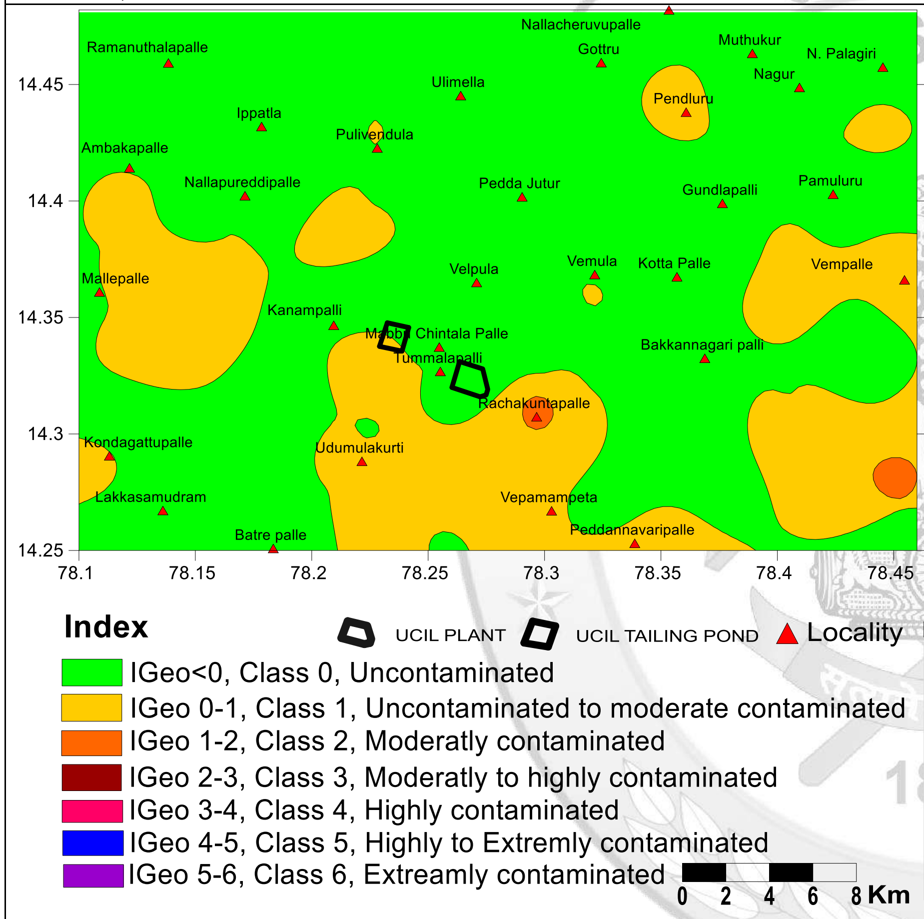


Fig:7.19 Spatial distribution of Enrichment factor map showing Ni (ppm) in Soil and Bar graph of Regolith and C-Horizon in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

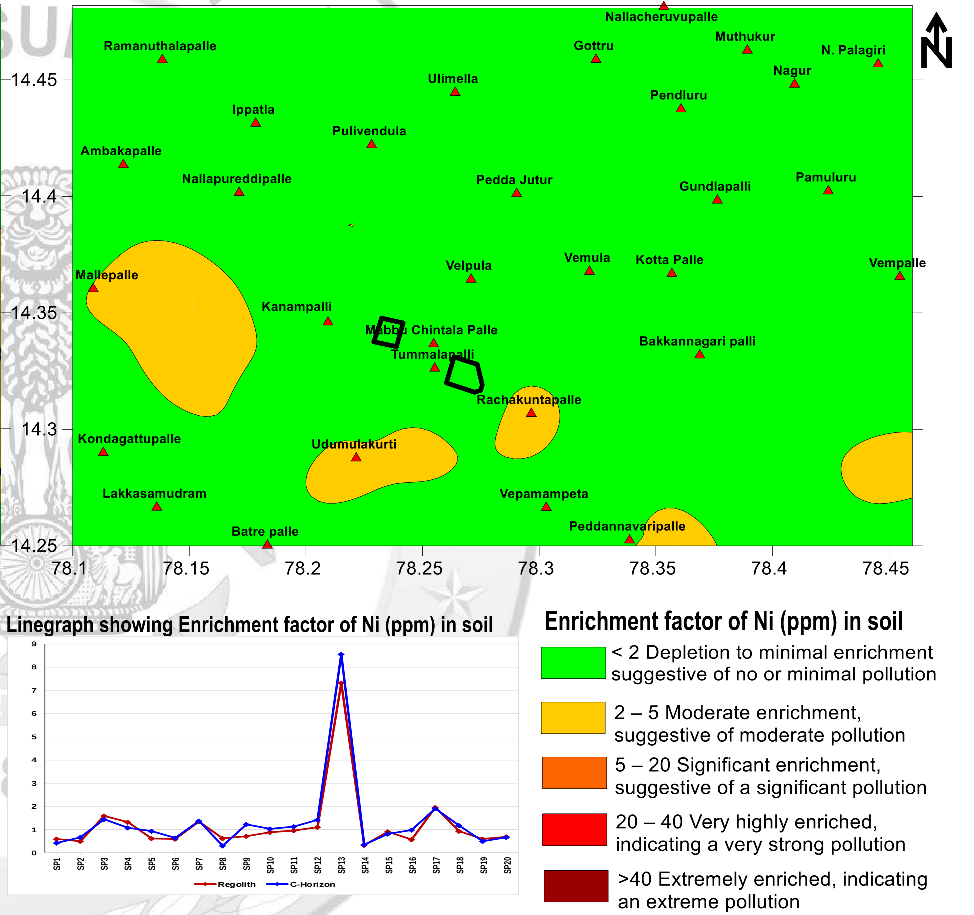


Fig:7.20 Geoaccumulation index map of Co (ppm) showing level of contamination in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

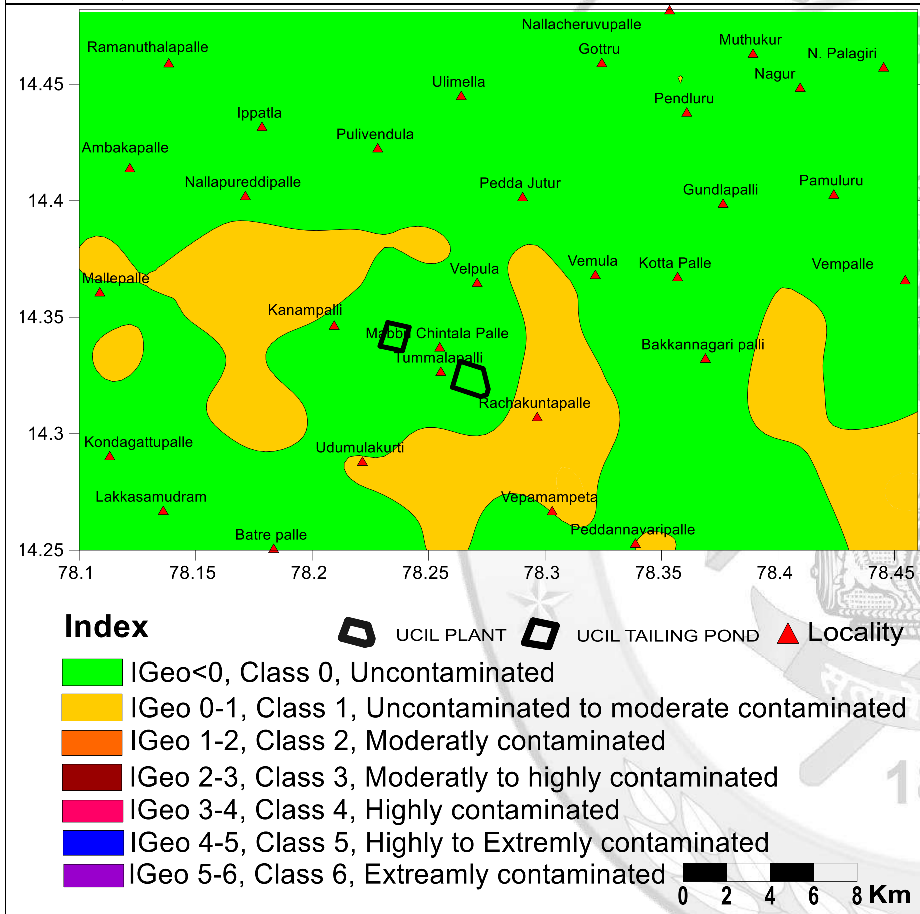


Fig:7.21 Spatial distribution of Enrichment factor map showing Co (ppm) in Soil and Bar graph of Regolith and C-Horizon in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

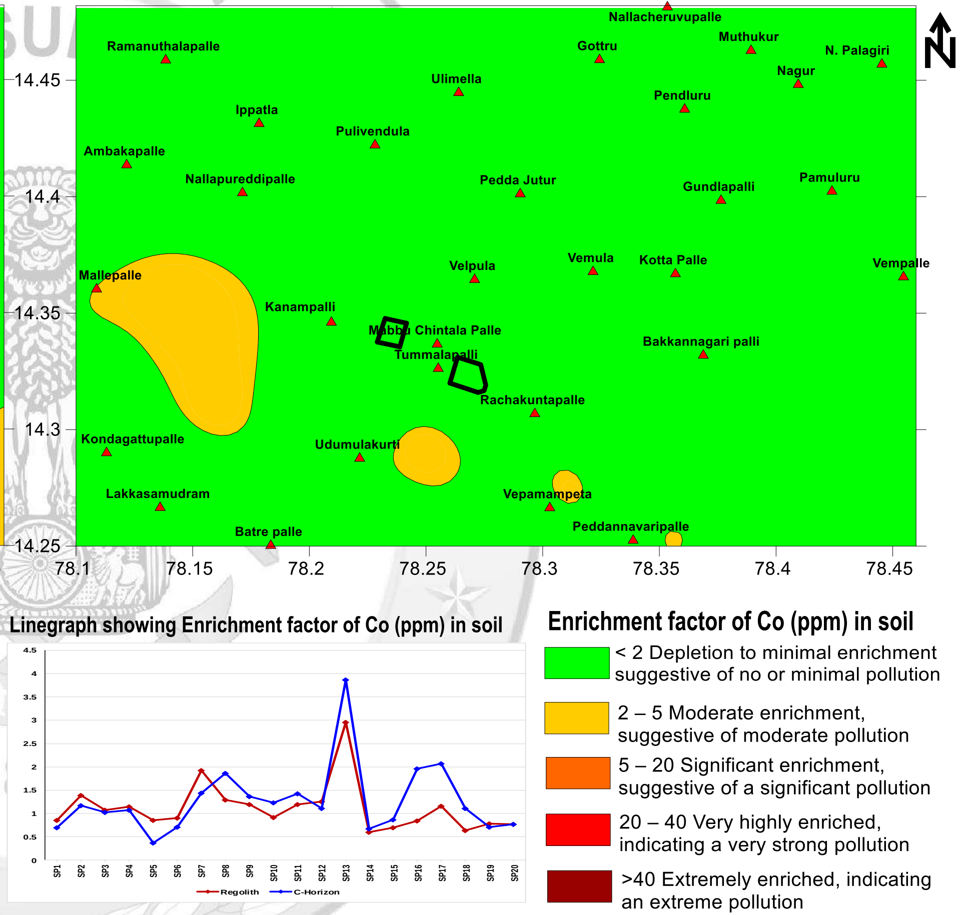


Fig:7.20 Geoaccumulation index map of Cr (ppm) showing level of contamination in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

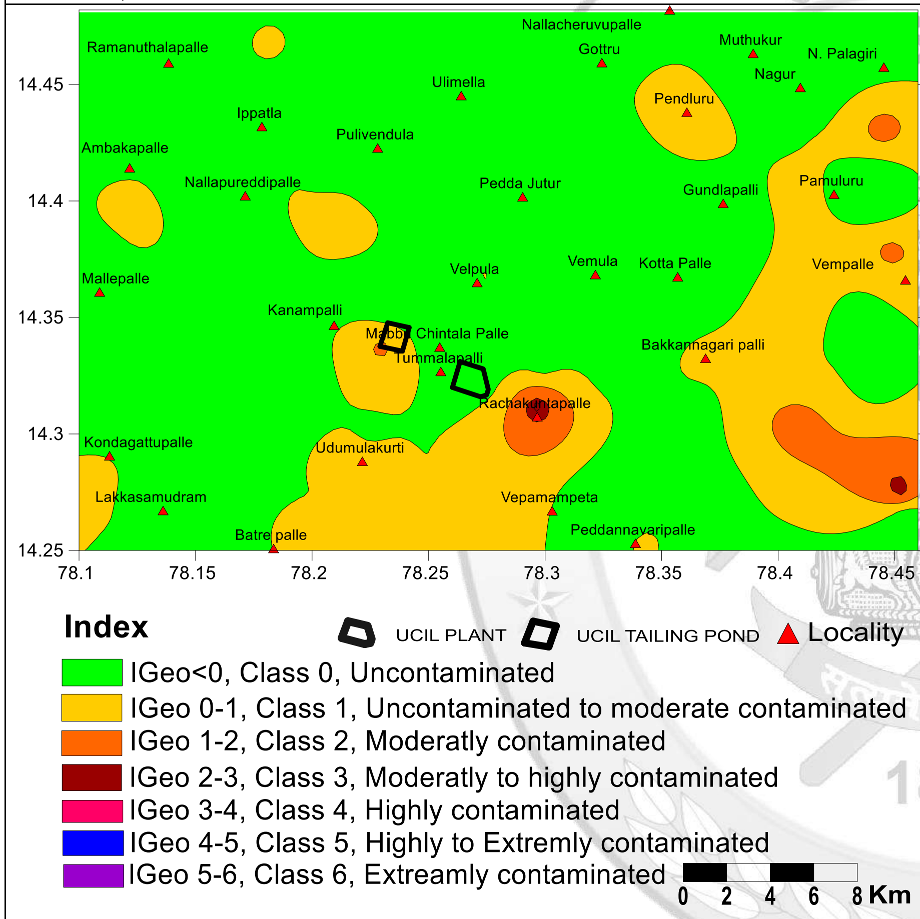
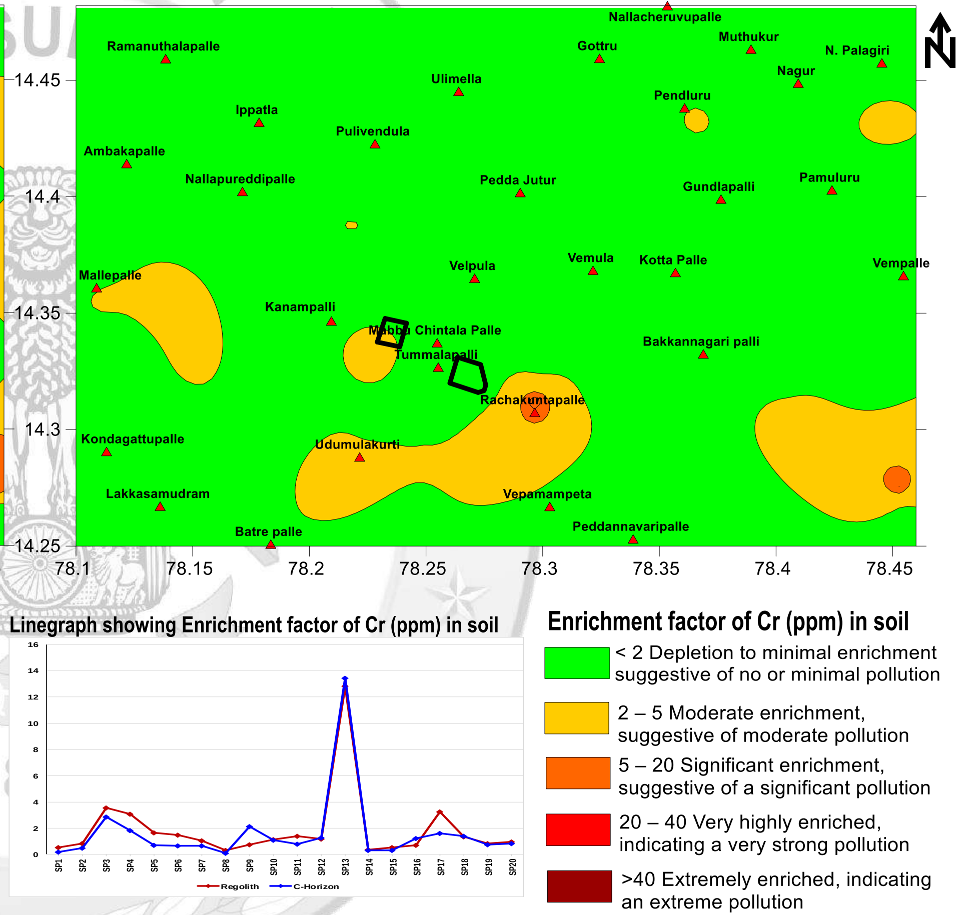


Fig:7.21 Spatial distribution of Enrichment factor map showing Cr (ppm) in Soil and Bar graph of Regolith and C-Horizon in Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



7.4 Weathering Indices:

The soil evolution degree was studied by the means of weathering indices described in the literatures (Parker, 1970, Perri, F2020) [5,6,11–14,27]. Most of these indices are conceived as molar ratios among elements with different mobility during silicate weathering. Since the same element could be associated with several mineral types, its distribution among them should be previously checked. More often, there is a greater possibility in the case of CaO to be present in different minerals such as carbonates, phosphates and silicates. In the Mănăila soil, the CaO distribution among carbonate, apatite and silicates (CaO*) was not possible for two reasons: (i) acidic pH and very low CaO% content do not fulfill the conditions of secondary carbonate existence; (ii) high P2O5 content sometimes requires a higher CaO than is found in soil. Thus, the CaO* corresponding to silicates was attributed to total molar CaO from analyses

Weathering indices are commonly used to quantitatively evaluate changes caused by chemical weathering in different materials (Birkeland, 1999; Darmody et al., 2005; Vogt, 1927; Ruxton, 1968; Harnois, 1988). The indices are based on the principle that the ratio between concentrations of mobile (e.g. SiO2, CaO, MgO and Na2O) and immobile (e.g. Al2O3, Fe2O3 and TiO2) elements will decrease over time as leaching progresses. However, the weathering of heterogeneous metamorphic rocks confounds the understanding of the relationship between the weathering index and depth (Dengiz et al., 2013).

Climate is a major influence on weathering processes affecting soil parent materials. Important contributors to soil formation in arid and semi-arid climatic zones are the diurnal cycles of solar heating and cooling that cause mechanical or physical disintegration of rock or parent materials, and wind-blown sands that score and abrade exposed rock surfaces. Weathering indices are the parameters which can be used for determining the degree of weathering and can be used to study the extent and nature of weathering in the soil horizons with the help of certain oxides. Thus the behavior of oxides in each soil profile can be well explained with these indices. Weathering indices calculated from elemental oxide concentrations in molecular proportions of the oxides of major elements are also used to evaluate the vertical changes in a weathering profile. The molecular proportion of each oxide is easily calculated from the percentage of the oxide based on weight. In addition, generally, weathering indices change systematically for soil profiles formed from homogeneous parent rocks with depth.

7.4.1 Calculation of weathering indices

Numerous indices, including those of Nesbitt and Young (1982) and Harnois (1988), have been developed to characterize chemical weathering in soils. Weathering indices used to quantify chemical weathering intensity in the current study included the Chemical Index of Alternation (CIA) (Nesbitt and Young, 1982), Chemical Index of Weathering (CIW) (Harnois, 1988), Weathering Index of Parker (WIP), (Parker, 1970), Plagioclase Index of Alteration (Fedo et al., 1995) and Ruxton ratio (Ruxton, 1968). CaO* represents the CaO contained only in the silicate fraction and is corrected for carbonate and apatite content. It is based on the assumption for CaO* that the molar CaO/Na2O ratio of silicates is not higher than one. As the molar CaO content (corrected for apatite) was less than the molar Na2O content, the value was taken as CaO*. On the other occasions, the CaO content of silicates was supposed to be equivalent to the molar Na2O content (McLennan, 1993).

Table: 7.4 Weathering indices of Regolith (R) and C-Horizon (C) in .

Sample no	CIA		CIW		R		PWI		PIA		WIP		* Rock type
	R	C	R	C	R	C	R	C	R	C	R	C	
SP1	67.50	77.50	77.81	87.30	4.97	3.46	79.15	73.50	73.80	85.90	3.07	3.04	PGC-II
SP2	74.20	80.80	89.83	94.91	4.69	3.52	78.98	73.58	87.10	93.80	3.64	3.87	PGC-II
SP3	73.10	36.60	76.73	37.52	3.82	4.80	72.02	76.77	75.50	35.90	8.96	13.56	BR-IR
SP4	61.30	53.10	64.93	56.02	5.46	4.08	78.95	74.73	62.70	53.40	9.39	8.27	PGC-II
SP5	65.30	85.40	79.92	94.55	5.23	2.98	82.57	72.72	74.20	93.90	2.27	2.30	PGC-II
SP6	64.50	78.40	78.66	88.64	5.52	3.44	83.10	75.45	72.60	86.90	1.93	2.20	PGC-II
SP7	73.40	68.10	87.90	87.64	11.98	10.07	88.78	87.07	84.30	82.70	3.21	2.81	SH-CG
SP8	32.50	42.30	33.64	43.63	4.78	5.09	76.23	74.63	31.10	41.80	16.44	16.20	BR-CG
SP9	70.40	37.90	72.69	38.18	5.19	5.74	75.11	76.64	71.80	37.70	6.30	18.38	BR-CG
SP10	46.50	33.20	50.36	34.96	6.41	5.29	81.47	79.43	45.90	31.40	12.49	14.94	D-CG
SP11	43.80	24.20	47.50	24.94	7.71	4.87	83.15	77.48	42.60	22.50	26.68	20.09	D-CG
SP12	52.90	73.30	57.64	83.10	7.66	8.30	84.35	85.37	53.40	80.50	9.04	7.04	D-CG
SP13	31.70	28.90	32.03	29.13	4.48	6.22	73.41	72.52	31.20	28.60	19.03	32.07	BR-CG
SP14	82.80	83.20	89.90	91.44	6.15	6.08	78.15	78.64	88.90	90.50	3.62	4.08	SH-CG
SP15	86.60	26.30	91.19	26.69	3.60	5.59	70.07	77.29	90.70	25.70	2.76	7.37	BR-CG
SP16	19.80	10.90	21.66	11.27	7.85	10.96	82.92	87.73	13.80	7.80	29.07	50.92	SH-CG
SP17	37.40	13.70	39.71	13.94	6.76	7.65	82.66	83.95	35.70	12.20	15.55	23.38	D-CG
SP18	53.10	41.00	61.71	45.08	7.07	6.30	84.91	83.39	54.30	39.00	6.90	12.58	SH-CG
SP19	75.50	61.50	89.03	69.55	4.79	5.18	78.17	78.98	86.60	65.00	5.78	7.64	SH-CG
SP20	77.00	55.70	90.43	63.40	4.34	4.74	76.08	78.40	88.40	57.70	5.36	7.74	SH-CG

* PGC-II- Peninsular Gneissic-II Group BR-I- Baisc rock intrusive, SH-CG Shale, Cuddapah Group, D-CG- Dolomite, Cuddapah Group, BR-CG- Basic rock Cuddapah Group.

7.4.2 Chemical Index of Alteration (CIA) in Soil (R & C-horizon) Samples

Soil is the surface layer of the mantle of rock-waste in which the physical and chemical processes of weathering co-operate in intimate association with biological processes and along with the climate plays a vital role in its formation. This is the reason for which the nature of soil varies both laterally as well as vertically with depth. Topsoil or "R" experience more alteration history than the subsoil or "C-horizon" which is a partly weathered portion with vestiges of bed rock, as rain leaches the soluble materials like alkalis of the soil profiles leaving behind the resistant minerals. The chemical index of alteration was proposed by Nesbitt and Young (1982) is a well-established parameter for determining the degree of weathering. CIA applied on soil maturity studies considers the loss of mobile elements in relation with aluminum oxide assumed to be the most important and abundant immobile elements during weathering. During the degradation of feldspars, Ca, Na, and K are removed and clay minerals with a higher fraction of Al are formed. CIA is estimated from the proportion of Al_2O_3 vs. the weathering-prone oxides. The formula used for calculation CIA is given below:

$$\mathbf{CIA = (Al_2O_3) / (Al_2O_3 + CaO^* + Na_2O + K_2O) \times 100}$$

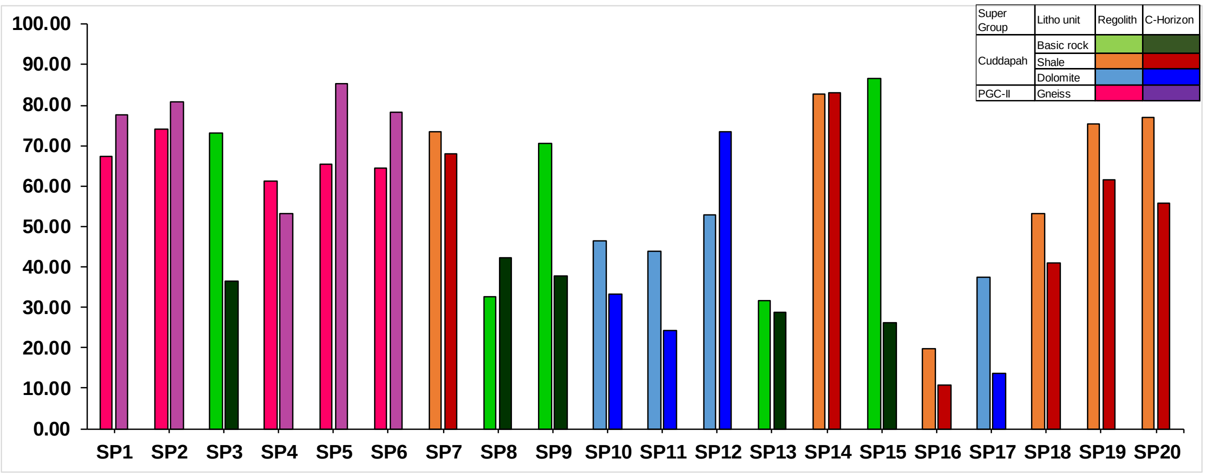
Where CaO* represents the amount of CaO incorporated in the silicate fraction. Nesbitt and Young (1982) classified the CIA values as unaltered feldspars (50), very slightly weathered (50 to 60), slightly weathered (60 to 70), moderately weathered (70 to 80), highly weathered (80 to 90), and extremely weathered (90 to100).

Soil profiles in the Penisular Gneissic group-II (PGC-II) shows that the CIA values varied from 61.30 to 74.20 Regolith and 53.10 to 85.40 in C-Horizon. Only one profile no SP-04 is high CIA values Regolith rather than C-Horizon and the rest of 04 profiles the profiles' CIA values increases in C-Horizon and decreased with depth in all profiles in Regfolith (Fig.7.33) CIA values of all layers concerning the classified the CIA values Nesbitt and Young (1982) (Table 7.4) overally CIA values of soil profile developed in PGC-II group of rocks shows that slightly weathering in Reolith and moderate in C-Horizon.

Soil profiles of the Cuddapah group rocks shows, the CIA values varied from 22.97 to 79 in Regolith and 8.91 to 85.18 in C-Horizon. High CIA values C-Horizon rather than Regolith and rest of the profiles CIA values increases in Regolith and decreased with depth in all profiles in C-Horizon (Fig.7.33). CIA values Regolith and C-Horizon may indicate that the proportion of alumina to alkalis in some of the samples is more in the R than that of C-Horizon and otherwise, although both the horizons consist of products of weathering. These CIA values may indicate the moderate to high weathering of granitic rocks concerning the classified CIA values Nesbitt and Young (1982) (Table 7.4).

The CIA classification was applied to the litho units occupied in the study which may states that the Regolith and C- horizons of the Cuddapah super group of rocks occupied area is as very slightly to moderately weathered compared to the Peninsular Gneissic –II group of rocks are moderate to highly weathered.

Fig.7.33 Bar graph comparing the CIA values of Regolith and C –Horizons of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



7.4.3 Chemical Index of Weathering (CIW) in Soil (R & C-horizon) Samples:

Harnois (1988) proposed the Chemical Index of Weathering (CIW) which modified CIA by excluding K_2O from assessments. Because the CIW does not account for the aluminium associated with K-feldspar, it may generate very high values for K-feldspar-rich rocks, whether they are chemically weathered or not (Fedo et al.,1995).

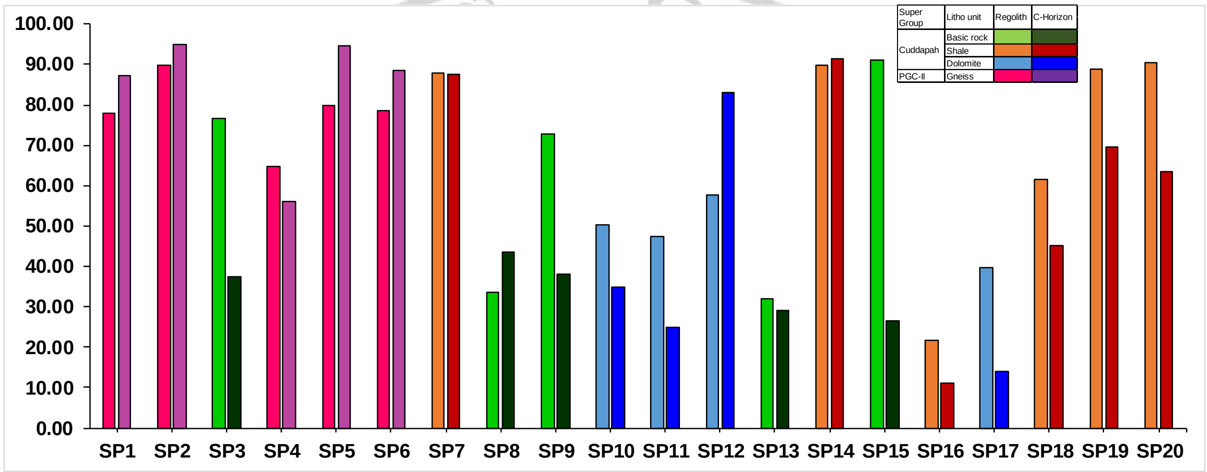
A weathering index should: (t) include only those elements which have consistent geochemical behaviour during weathering; (2) be independent of the degree of oxidation of the weathered material; (3) involve chemical elements commonly reported in soil analyses; and (4) be as simple as possible and easy to use. Using these criteria, the proposed CIW index is an improved measure of the degree of weathering experienced by a material relative to its source rock: CIW = $[Al_2O_3/ (Al_2O_3 + CaO^* + Na_20)]$ X 100

where Al_2O_3, CaO, and Na_2O are in molecular proportions. In the proposed index, Al_20_3 is used as the immobile component. CaO and Na_20 are the mobile components because they are readily leached during weathering. This index does not incorporate potassium because it may be leached or it may accumulate in the residue during weathering.

In the study area, the CIW values ranged between 64.93 to 89.83 in Regolith and 56.02 to 94.91 in C-Horizon in Penisular Gneissic group-II (PGC-II) , values vary from 23 to 92 in Regoilth and 9 to 89 in C-Horizon in Cuddapah Group (Table 7.4). It has been observed that the CIW high values observed in Cuddapah Super group of rocks in Regolith is greater than that of C Horizon and vice versa. Based on the CIW pattern is more in Peninsular

Gneissc –II group R samples lower when compare to the C-Horizonively to the Hutti- Maski Group. The CIW index increases with the degree of depletion of the Regolith and C-Horizon in Na and Ca, relative to Al. The difference between CIW index values for source rock and soil or sediment reflects the amount of chemical weathering experienced by the weathered material (Fig. 7.34)

Fig.7.34 Bar graph comparing the CIW values of Regolith and C –Horizons of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



7.4.4 Ruxton Ratio (R)

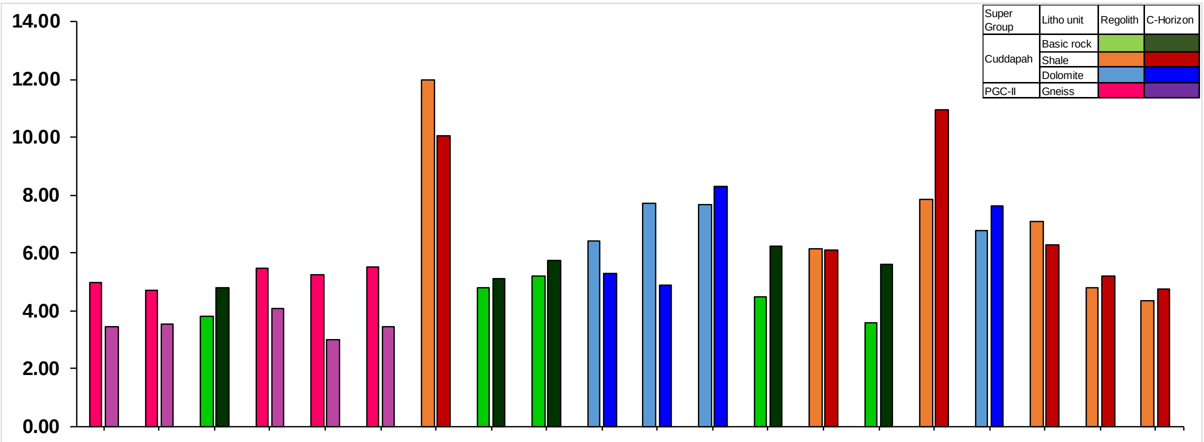
The simple weathering index, proposed by Ruxton (1968) was termed as Ruxton Ratio by Chittleborough (1991), is best suited for weathering profiles developed on uniform acidic to intermediate bedrock. The Ruxton Ratio relates silica loss to total element loss and considers alumina (and other sesquioxides) to be immobile during weathering. Ruxton (1968) tested Ruxton Ratio (R) on weathering profiles developed on igneous and metamorphic rocks from humid regions around the world, and found that Ruxton Ratio (R) can be very well correlated with the total element loss. The Ruxton Ratio (R) can be calculated as ratio of SiO_2 and Al_2O_3.

$$[\{\text{Ruxton Ratio (R)}\} = SiO2/Al2O3]$$

where optimum fresh value is 10 and the optimum weathered value is 0.

Based data it has been noticed that the Ruxton Ratio (R) values, 05 nos of profiles high in R(Regolith) are less in C-Horizon in Peninsular Gneissic complex group (PGC-II), 05 nos of samples high in C-Horizon in Bsic rock, 03 nos of samples in Shale and 02 nos of samples in Dolomite from Cuddapah group (Table 7.4) (Fig.7.35). It may clearly state that the silica loss is more in Regolith portion of Peninsular Gniessic group rest of the Cuddapah group. This means that the silica loss is less in Regolith than that of in C-Horizon which also proves that the the low rate of chemical weathering which is witnessed by high Ruxton ratio in both the soil horizons. These results are the illustration of less rainfall and dry and arid climatic condition in the reagion.

Fig.7.35 Bar graph comparing the Ruxton values of Regolith and C –Horizons of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

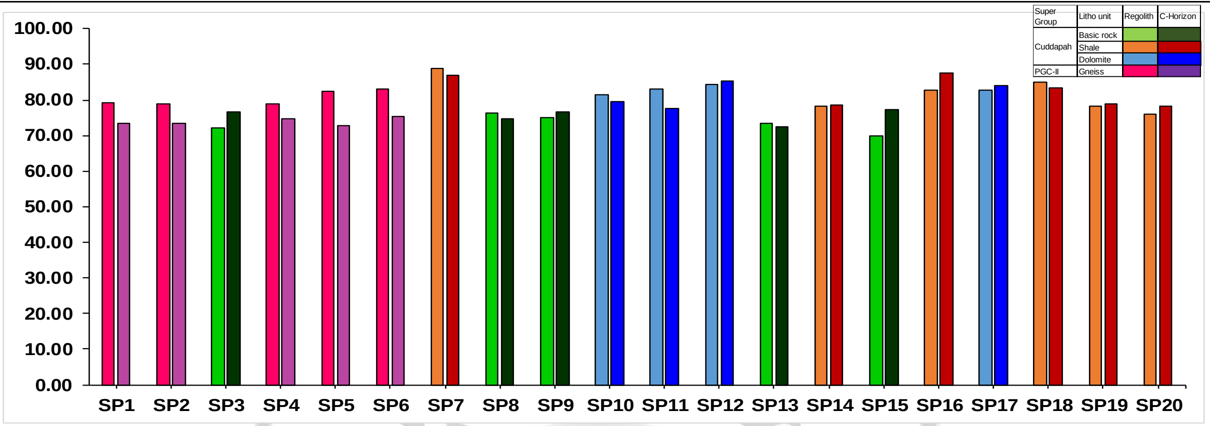


7.4.5 Product of Weathering Index (PWI)

This index was introduced by Souri, et al (2006) to study soil weathering from different regions in Japan. They combined the PWI with the WIP to track soil weathering in a two-dimensional coordinate system where the axes are Parker and Product indexes. Product of Weathering Index (PWI) can be used to identify the initial and lateral products of weathering which can be tracked at the same time. PWI is used to track movements of less mobile elements. Based on the principle of PWI, as the values of the indices get smaller, the samples are more weathered and assumed to be elder. The formula for calculating PWI is given below: PWI = (SiO_2)/ (TiO_2+ Fe_2O_3+ SiO_2+ Al_2O_3) X 100

Where optimum fresh value is greater than 50 and the optimum weathered value is 0. In below data it has been observed the Product of Weathering Index (PWI) shows higher index values indicates less mobiles oxide minerals not leached out from the soil represents low chemical weathering leads to less leaching of immobile elements. Whereas, less variation has seen in vertical profile (Table 7.4) (Fig. 7.36).

Fig.7.36 Bar graph comparing the PWI values of Regolith and C –Horizons of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh

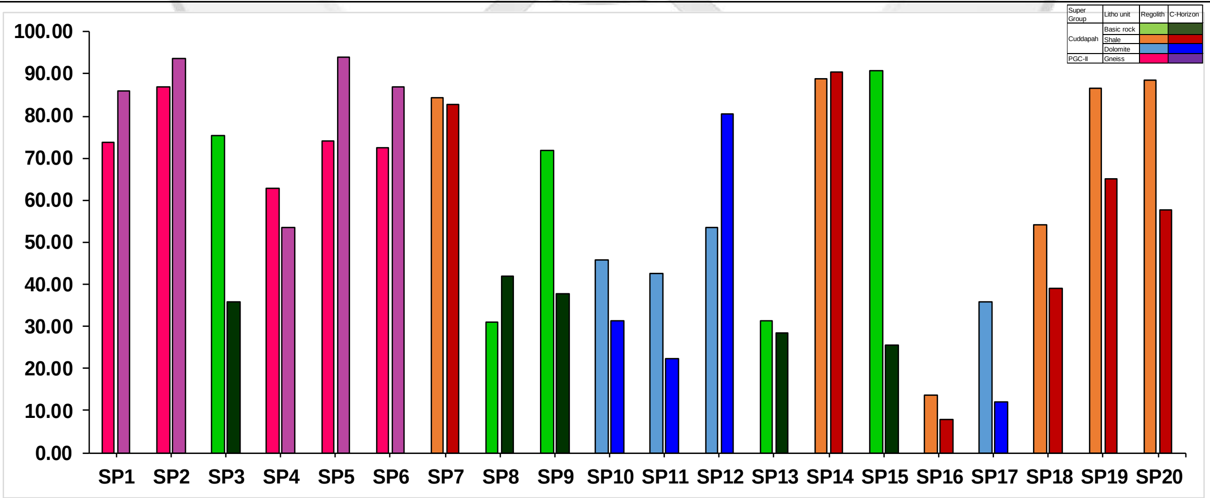


7.4.6 Plagioclase index of alteration (PIA): Plagioclase Index of Alteration as an alternative to the CIW. Because plagioclase is abundant in silicate rocks and dissolves relatively rapidly, the PIA may be used when plagioclase weathering needs to be monitored (Fedo et al., 1995). Plagioclase index of alteration (PIA) excludes K_2O from the CIA formula because of non-consistent behavior of K during supergene K-feldspar weathering.

$$PIA = [(Al_2O_3 - K_2O) \times 100]/ (Al_2O_3 + CaO + Na_2O - K_2O$$

The maximum PIA value is 100 (kaolinite, gibbsite) and unweathered plagioclase has a PIA of 50. In the present study, Highest PIA values in PGC_II and Low to moderate PIA values in Cuddapah group. it indicates that weathering of plagioclase is much more prone in the PGC-II. The PIA values tended to decrease with the depth in all profiles Cuddapah group and increasing tendency in PGC-II group (Fig.7.37) (Table 7.4).

Fig.7.37 Bar graph comparing the PIA values of Regolith and C –Horizons of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



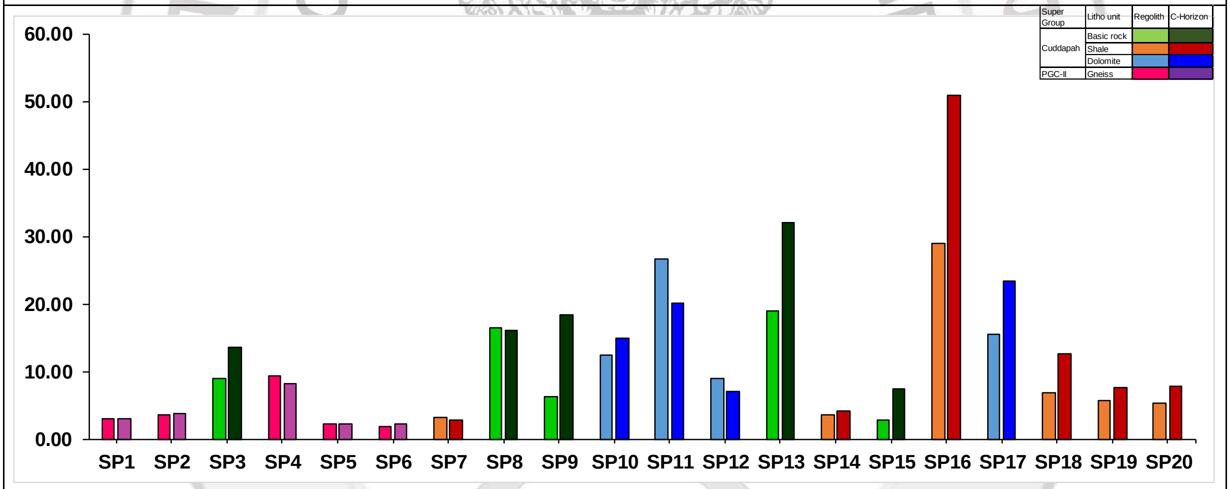
7.4.7 Parker's Weathering Index (WIP)

Parker (1970) was proposed WIP is used to evaluate the intensity of the weathering of silicate rocks, based upon the proportion of alkali and alkaline earth elements in the products of weathering. The WIP also takes into account some individual mobilities, namely sodium, potassium, magnesium and calcium, on the basis of their bond strengths with oxygen.

$$\mathrm{WIP} = (\mathrm{CaO}/0.7) + (2 \times \mathrm{Na_2O}/0.35) + (2 \times \mathrm{K_2O}/0.25) + (\mathrm{MgO}/0.9) \times 100$$

The low values point out a higher degree of weathering, whereas high values are typical of slightly weathered material. In the present study, the WIP values of the soils profiles collected in Peninsular gneissic-II group shows that to regolith and C-horizon subjected to higher degree of weathering, except one samples having slight weathering (Fig 7.38) (Table 7.4).

Fig.7.38 Bar graph comparing the WIP values of Regolith and C –Horizons of Tummalapalli area, Y.S.R Kadapa and Anantapur districts, Andhra Pradesh



CHAPTER- 8

HYROGEOCHEMISTRYOF SURFACE AND SUBSURFACE WATERS

INTRODUCTION

Water is indeed the elixir of life, and securing access to safe drinking water is a critical challenge for humanity, especially in the face of growing global pressures on freshwater resources. Addressing this challenge requires a concerted effort at the local, national, and global levels to ensure that water remains a basic human right and a sustainable resource for future generations. Efforts to protect and improve drinking water quality involve comprehensive water resource management, pollution prevention, and treatment technologies. Regulations and standards are established to safeguard water quality, and public education is essential to promote responsible water use and protection of water sources.

Table: 8.1 Descriptive statistics of physico-chemical analysis data for Ground water samples

Parameter	**Pre-Monsoon**			**Post-Monsoon**			**BIS (2012) *WHO**	
	Min	Max	Avg	Min	Max	Avg	acceptable	Permissible
pH	6.50	8.30	7.33	6.90	9.33	7.52	6.5-8.5	
EC in µS/cm	460.00	15750.00	1764.46	61.00	6340.00	1533.98		
TH CaCO3 in mg/L	100.00	4000.00	485.94	25.00	1400.00	446.93	200	600
Ca^{2+}in mg/L	8.02	420.84	56.73	2.00	160.32	66.84	75	200
Mg^{2+}in mg/L	7.29	716.85	83.69	4.86	291.60	68.28	30	100
Na^{+} in mg/L	11.50	1775.00	168.26	0.18	921.00	134.95		*200
K^{+} in mg/L	0.23	477.50	15.30	0.19	1347.70	27.22		*12
Cl^{-} in mg/L	21.27	3403.20	203.62	3.54	1382.55	180.87	250	1000
SO_4^{2-} in mg/L	1.44	1228.50	76.19	1.63	700.00	76.82	200	400
NO^{3-} in mg/L	**0.95**	**2232.00**	**112.23**	**0.23**	**457.28**	**76.55**	**45**	
F^{-} in mg/L	0.18	5.64	1.36	0.16	5.26	1.35	1	1.5
Alkalinity	70.00	1550.00	402.99	10.00	1185.00	392.70		
Turbidity (NTU)	2.00	4.90	3.29	0.80	3.00	1.80		
HCO^{3-} in mg/L	85.43	1891.62	491.07	6.10	1446.17	477.10		
TDS in mg/L	**259.00**	**9097.00**	**1016.95**	**28.00**	**3779.00**	**924.21**	**500**	**2000**
U in (ppb)	**0.31**	**1315.52**	**35.87**	**0.01**	**635.71**	**18.83**		
Fe in (ppb)	0.01	11.82	0.49	50.00	6795.96	327.77	0.3	
Ni in (ppb)	0.01	0.12	0.04	0.50	33.99	1.73	0.02	
Cu in(ppb)	0.01	0.12	0.02	0.25	180.46	6.74	0.05	1.5
Zn in (ppb)	0.01	4.03	0.21	1.00	2303.83	100.70	5	15
As in (ppb)	**0.09**	**9.17**	**0.86**	**0.50**	**14.73**	**1.57**	**0.01**	
Se in (ppb)	0.01	1.61	0.28	50.00	50.00	50.00	0.01	
Cd in (ppb)	0.01	4.78	0.12	0.01	2.13	0.10	0.003	
Cr in (ppb)	0.01	0.02	0.01	2.00	21.95	2.25	0.05	
Mn in (ppb)	0.01	6.56	0.12	0.25	413.43	21.36	0.1	0.3
Pb in (ppb)	0.02	33.73	1.74	0.25	45.75	2.03		0.01

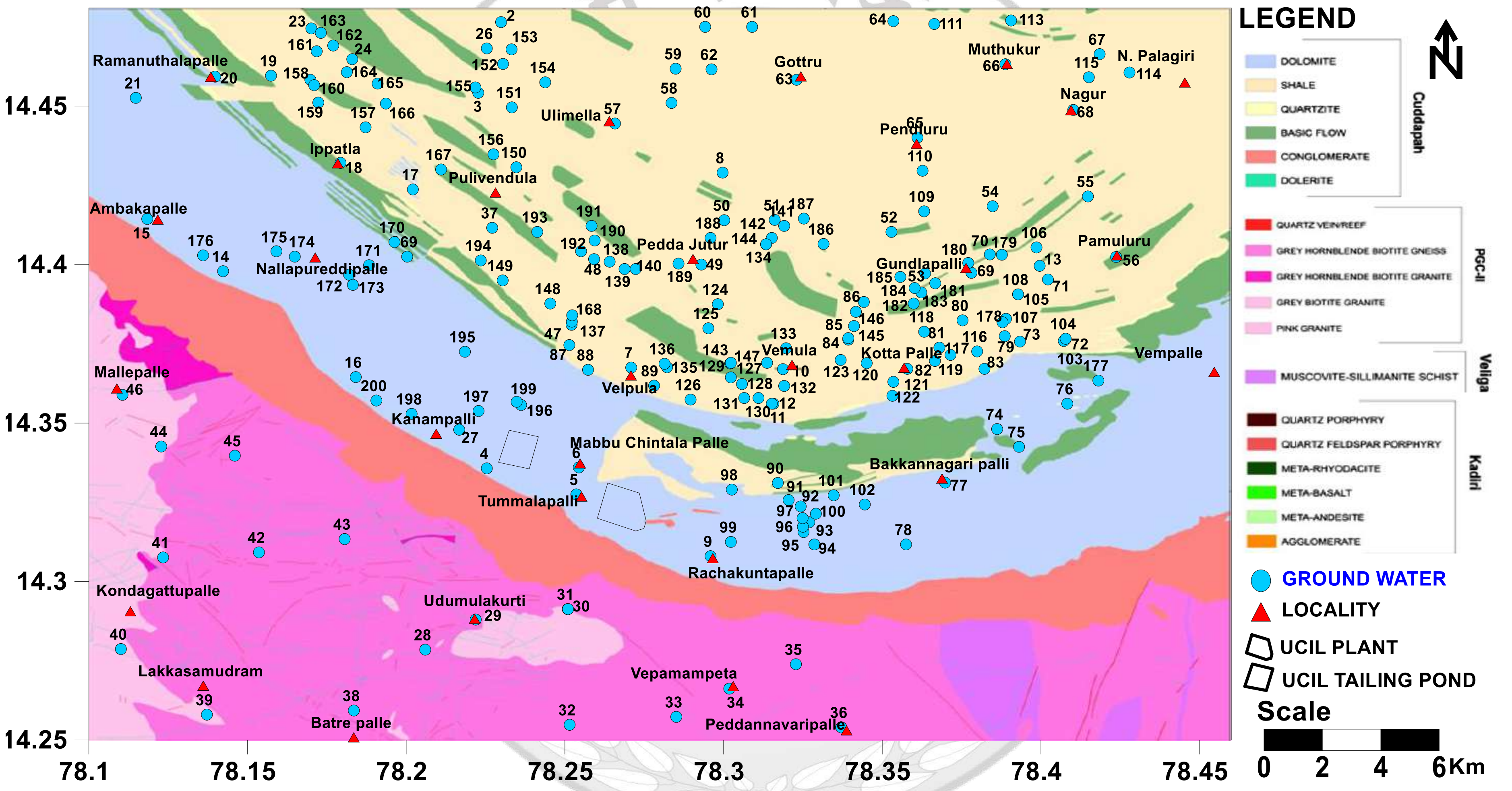
Table: 8.2 Correlation matrix for Major ions with U, F, As, Pb etc in ground water samples from pre monsoon

	pH	*E C*	*TH*	*Ca*	*Mg*	*Na*	*K*	*Cl*	*SO4*	*NO3*	*F*	*HCO3*	*TDS*	*U*	*Fe*	*Ni*	*Cu*	*Zn*	*As*	*Se*	*Cd*	*Cr*	*Mn*	*Pb*
pH	1.0																							
EC	-0.2	1.0																						
TH	-0.4	0.8	1.0																					
Ca	-0.5	0.6	0.8	1.0																				
Mg	-0.4	0.8	1.0	0.7	1.0																			
Na	0.0	0.9	0.5	0.4	0.5	1.0																		
K	0.1	0.4	0.0	0.0	0.0	0.5	1.0																	
Cl	-0.2	0.9	0.9	0.7	0.9	0.8	0.2	1.0																
SO4	0.1	0.6	0.2	0.2	0.1	0.7	0.6	0.3	1.0															
NO3	-0.3	0.9	0.9	0.7	0.8	0.7	0.3	0.8	0.3	1.0														
F	0.3	0.2	-0.2	-0.1	-0.2	0.4	0.3	0.0	0.3	-0.1	1.0													
HCO3	0.1	0.6	0.2	0.1	0.2	0.7	0.5	0.4	0.5	0.3	0.6	1.0												
TDS	-0.2	1.0	0.8	0.6	0.7	0.9	0.5	0.9	0.6	0.9	0.2	0.6	1.0											
U	0.0	0.0	0.0	0.1	-0.1	0.0	0.0	-0.1	0.1	-0.1	0.2	0.0	0.0	1.0										
Fe	-0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.1	-0.1	1.0									
Ni	0.5	-0.4	-0.5	-0.6	-0.4	-0.3	0.3	-0.2	0.0	-0.4	-0.4	-0.5	-0.4	-0.4	0.3	1.0								
Cu	-0.3	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.2	-0.2	-0.1	-0.1	0.2	0.5	1.0							
Zn	-0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.0	0.2	-0.1	0.1	0.2	-0.1	0.5	-0.1	0.2	1.0						
As	0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.2	0.2	0.0	0.0	-0.1	-0.1	0.0	-0.1	1.0					
Se	-0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	-0.1	0.0	0.4	-0.1	0.0	0.0	-0.1	0.0	1.0				
Cd	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.2	0.0	0.1	0.1	0.1	0.3	0.0	-0.3	-0.1	0.1	0.2	0.0	1.0			
Cr	-0.6	-0.7	-0.3	0.5	-0.5	-0.6	-0.3	-0.3	0.0	-0.5	-0.7	-0.8	-0.6	0.8	0.4	-1.0	####	0.3	-0.6	0.1	-0.1	1.0		
Mn	-0.2	0.2	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.3	0.0	0.1	0.2	0.0	0.3	-0.3	0.2	0.2	0.0	-0.1	0.0	0.1	1.0	
Pb	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.5	0.1	0.1	0.5	-0.1	-0.1	0.1	0.4	0.1	1.0

Table: 8.3 Correlation matrix for Major ions with U, F, As, Pb etc in ground water samples from post monsoon

	pH	E C	TH	Ca	Mg	Na	K	Cl	SO4	NO3	F	HCO3	TDS	U	Fe	Ni	Cu	Zn	As	Cd	Cr	Mn	Pb
pH	1.00																						
E C	-0.16	1.00																					
TH	-0.36	0.71	1.00																				
Ca	-0.40	0.34	0.60	1.00																			
Mg	-0.26	0.70	0.95	0.32	1.00																		
Na	-0.01	0.83	0.34	0.05	0.38	1.00																	
K	0.01	0.32	0.07	0.13	0.03	-0.06	1.00																
Cl	-0.16	0.92	0.68	0.24	0.71	0.69	0.41	1.00															
SO4	-0.18	0.66	0.45	0.39	0.39	0.58	0.23	0.49	1.00														
NO3	-0.30	0.79	0.77	0.40	0.76	0.60	0.05	0.74	0.43	1.00													
F	0.21	0.21	-0.10	-0.12	-0.08	0.42	-0.08	0.03	0.11	-0.01	1.00												
HCO3	-0.06	0.64	0.37	0.15	0.37	0.72	-0.07	0.39	0.28	0.40	0.54	1.00											
TDS	-0.17	0.99	0.68	0.34	0.67	0.83	0.36	0.91	0.70	0.77	0.21	0.63	1.00										
U	0.00	0.13	0.04	0.07	0.01	0.18	-0.02	0.06	0.23	0.04	0.07	0.14	0.14	1.00									
Fe	-0.04	0.11	0.00	-0.06	0.02	0.18	-0.02	0.11	0.12	0.05	-0.02	0.09	0.13	-0.03	1.00								
Ni	-0.02	0.00	0.04	0.02	0.04	-0.07	0.06	0.02	-0.03	-0.03	-0.09	-0.04	-0.01	-0.05	-0.03	1.00							
Cu	0.09	-0.09	-0.14	-0.03	-0.12	-0.05	0.01	-0.05	-0.04	-0.08	-0.12	-0.17	-0.09	-0.04	0.30	0.01	1.00						
Zn	-0.17	0.04	0.07	0.11	0.04	0.01	0.00	0.02	-0.04	0.04	0.02	0.09	0.03	-0.04	0.21	0.18	0.17	1.00					
As	0.15	0.28	0.23	0.04	0.25	0.18	0.12	0.23	0.01	0.13	0.31	0.35	0.25	0.06	0.02	0.13	-0.07	-0.01	1.00				
Cd	-0.07	0.10	0.00	0.12	-0.05	0.16	-0.03	0.07	0.24	0.08	0.10	-0.05	0.11	0.00	0.14	0.13	0.09	0.20	0.06	1.00			
Cr	-0.09	0.03	0.13	0.05	0.13	-0.05	0.03	0.06	0.00	0.05	-0.08	-0.03	0.03	-0.03	0.17	-0.01	-0.01	-0.03	0.12	-0.04	1.00		
Mn	0.05	-0.02	-0.06	-0.03	-0.04	-0.03	0.11	0.00	0.03	0.01	-0.11	-0.10	0.00	-0.02	0.26	0.07	0.59	0.24	-0.09	0.24	-0.02	1.00	
Pb	-0.01	-0.06	-0.03	-0.07	-0.01	-0.07	0.00	-0.04	-0.09	-0.05	-0.05	-0.04	-0.07	-0.05	0.47	0.04	0.58	0.44	0.01	0.02	0.03	0.26	1.00

Fig. 8.1 Location map of water samples overlayed on the Geology map of the study area (Parts of Y.S.R. Kadapa and Anantapur districts)



8.2 MAJOR CATION AND ANION CHEMISTRY

pH: The pH scale measures the logarithmic concentration of hydrogen (H+) and hydroxide (OH-) ions. It is an important parameter in evaluating the acid–base balance of water and the indicator of acidic or alkaline condition of water status. The pH is 7.0 or neutral. According to the BIS and WHO recommended maximum permissible limit pH levels between 6.5 to 8.5. pH in water sample of the study area ranges from **6.5 - 8.3** with an average of **7.33** during pre-monsoon and ranges from **6.9 - 9.3** with an average of **7.52** during post-monsoon. (Table8.1). Most of samples from the study area are falling in the acceptable or safe range. The point anomaly map shows pH in water samples during pre and post monsoon (Fig.8.2-8.3). Higher pH values in 7 nos. of water samples during pre-monsoon are falling in the agricultural land and over Tadpatri shale of Cuddapah Supergroup in the northeast part of the study area, whereas 2 nos. of water samples during post-monsoon shows higher pH values falling over Tadpatri shale of Cuddapah Supergroup in the agricultural land. pH is basic nature which indicated that water is slightly alkaline in nature but suitable for domestic purposes (Herojeet et al., 2013). The slightly alkaline nature of water in the study area might be due to the presence of bicarbonates and carbonates in the underline lithology. The higher pH values lead to taste grievance and harmful impact on the eyes and skin.

Fig.8.2 Point anomaly map showing pH concentrations in pre-monsoon ground water samples overlying in Geological map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts

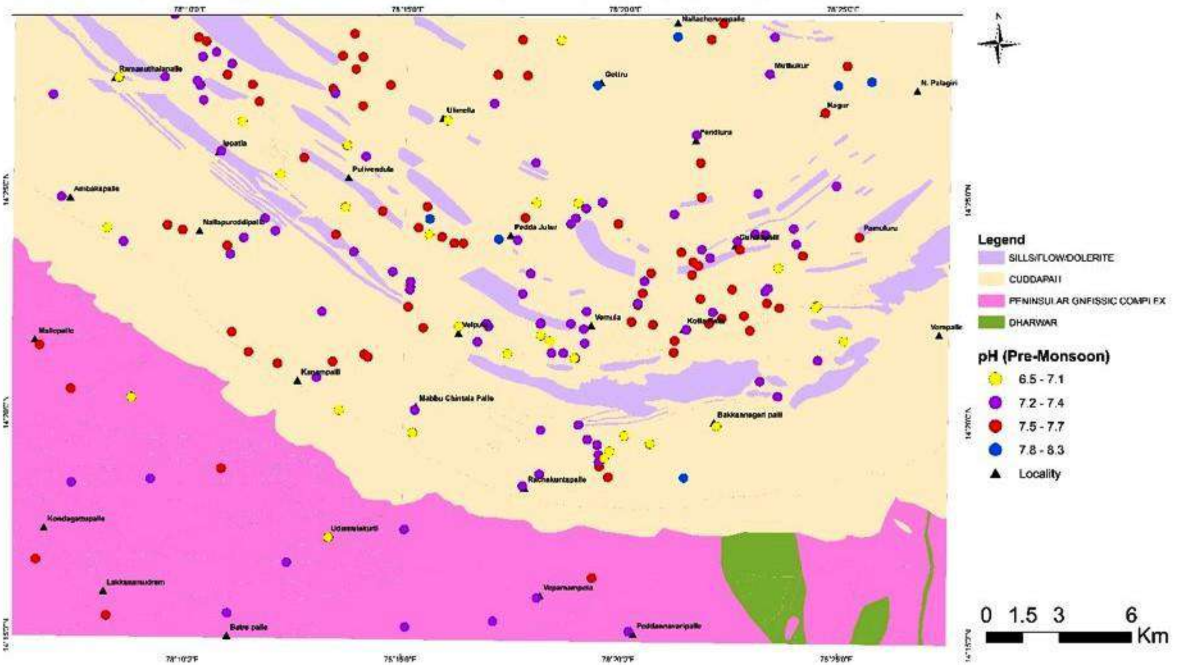
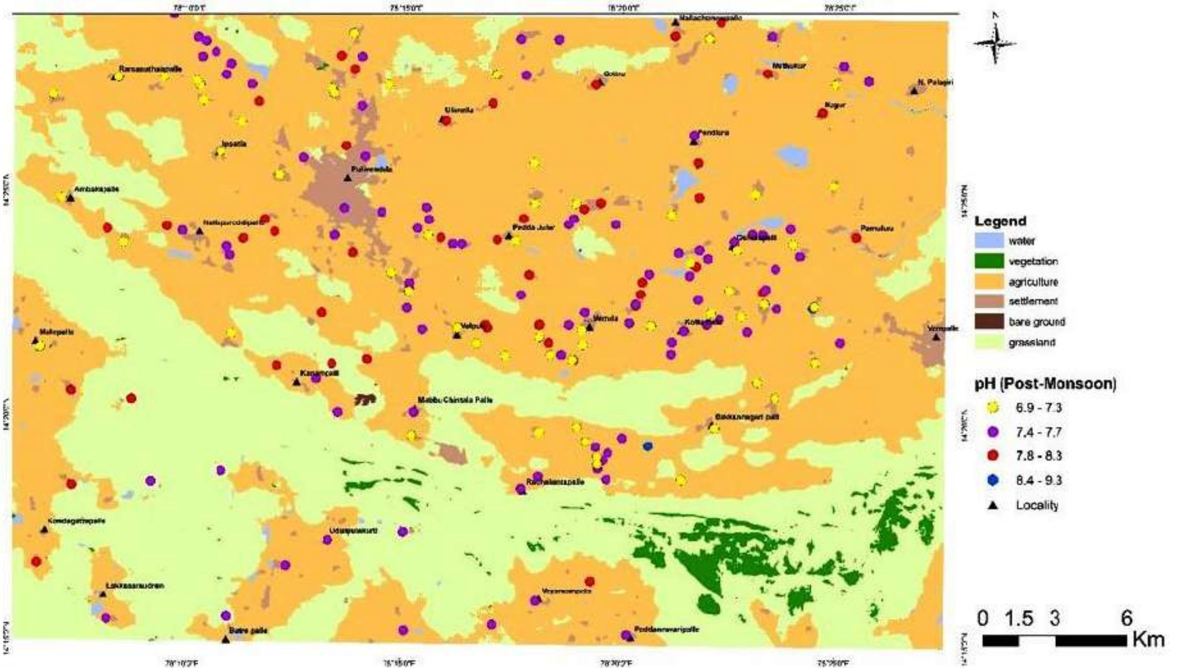


Fig.8.3 Point anomaly map showing pH concentrations in post-monsoon ground water samples overlying in Landuse-Land cover map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts



EC: Electrical conductivity of water is an important parameter for determining the water quality. It is a measurement of water’s capacity for carrying electrical current which is directly related to the concentration of ionized substance in the water. Conductivity shows significant correlation with ten parameters such as temperature, pH, value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water. Pure water is not a good conductor of electric current rather’s a good insulator. Increase in ions concentration enhances the electrical conductivity of water. High conductivity might be due to weathering of the rocks. Through weathering, small amounts of rock and other deposits are dissolved and carried away by water. This slow weathering may cause accumulation of salts in streams thus increasing the electrical conductivity. Electrical conductivity (EC) actually measures the ionic process of a solution that enables it to transmit current. The common unit for electrical conductivity is Siemens per meter(µS/cm). In most of the fresh water sources it ranges between 10 µS/cm to 1000 µS/cm. In the study area, EC values of water ranged between 460 µS/cm to 15,750 µS/cm with average value 1764.45 µS/cm in pre-monsoon and 61 µS/cm to 6340 µS/cm with average value 1533.98 µS/cm in post-monsoon (Table 8.1). Higher EC values in 11 nos. of water samples during pre-monsoon are falling in the agricultural land and over Tadpatri shale of Cuddapah Supergroup in the northeast part of the study area, whereas 7 nos. of water samples during post-monsoon shows higher EC values falling over Tadpatri shale of Cuddapah Supergroup in the agricultural land. All the water samples show high conductivity. These results clearly indicate that water in the study area was moderate to highly ionized and has the higher level of ionic concentration activity due to high dissolve solids (Fig.8.4-8.5).

Fig.8.4 Point anomaly map showing Ec (μS/cm) concentrations in pre-monsoon ground water samples overlying in Geological map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts

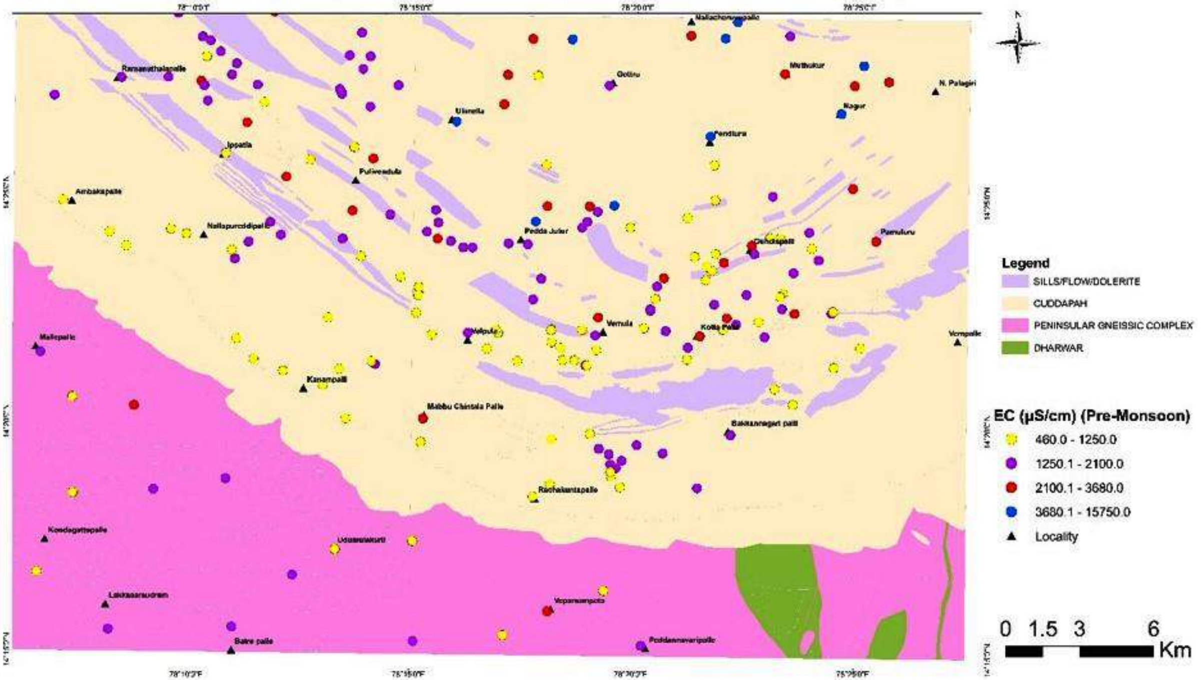
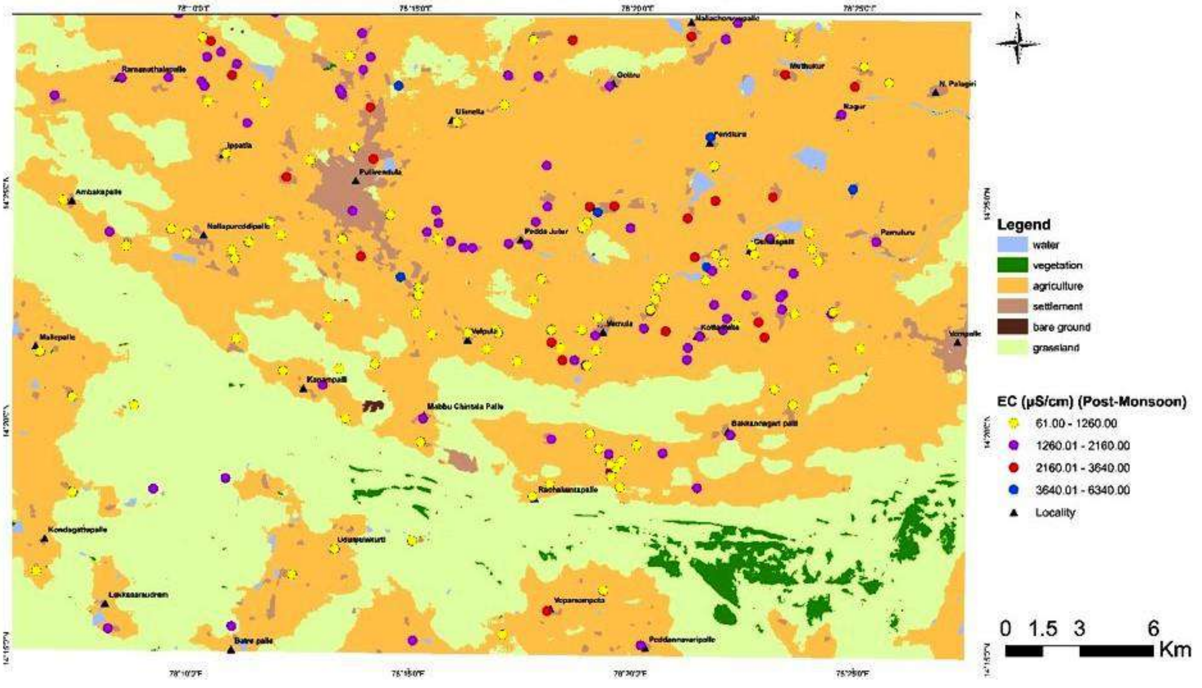


Fig.8.5 Point anomaly map showing Ec (μS/cm) concentrations in post-monsoon ground water samples overlying in Landuse- Land cover map of study area of the study area, Parts of Y.S.R. Kadapa and Anantapur districts



Total Dissolved Solids (TDS): Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates that are dissolved in water, expressed in mg per litre (mg/L). These minerals produced un-wanted taste and diluted color in appearance of water. This is the important parameter for the use of water. The water with high TDS value indicates that water is highly mineralized. Desirable limit for TDS is **500 mg/l** and maximum limit is **2000 mg/l** which prescribed for drinking purpose. The concentration of Total dissolved solids of water in study area varied from **259 mg/L** to **9097 mg/L** with an average value of **1016.95 mg/L** in **pre monsoon** and from **28 mg/L** to **3779 mg/L** with an average value of **924.21 mg/L** in **post monsoon** (Table8.1) (Fig.8.6-8.7) Higher TDS values in 2 nos. of water samples during pre-monsoon are falling in the agricultural land and over Tadpatri shale of Cuddapah Supergroup in the northeast part of the study area, whereas 6 nos. of water samples during post-monsoon shows higher TDS values falling over Tadpatri shale of Cuddapah Supergroup in the agricultural land. High values of TDS in ground water are generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases. Water containing high solid may cause laxative or constipation effects according to Sasikaran et al. (2012).

Fig. 8.6 Point anomaly map showing TDS (mg/l) concentrations in pre-monsoon ground water samples overlying in Geological map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts

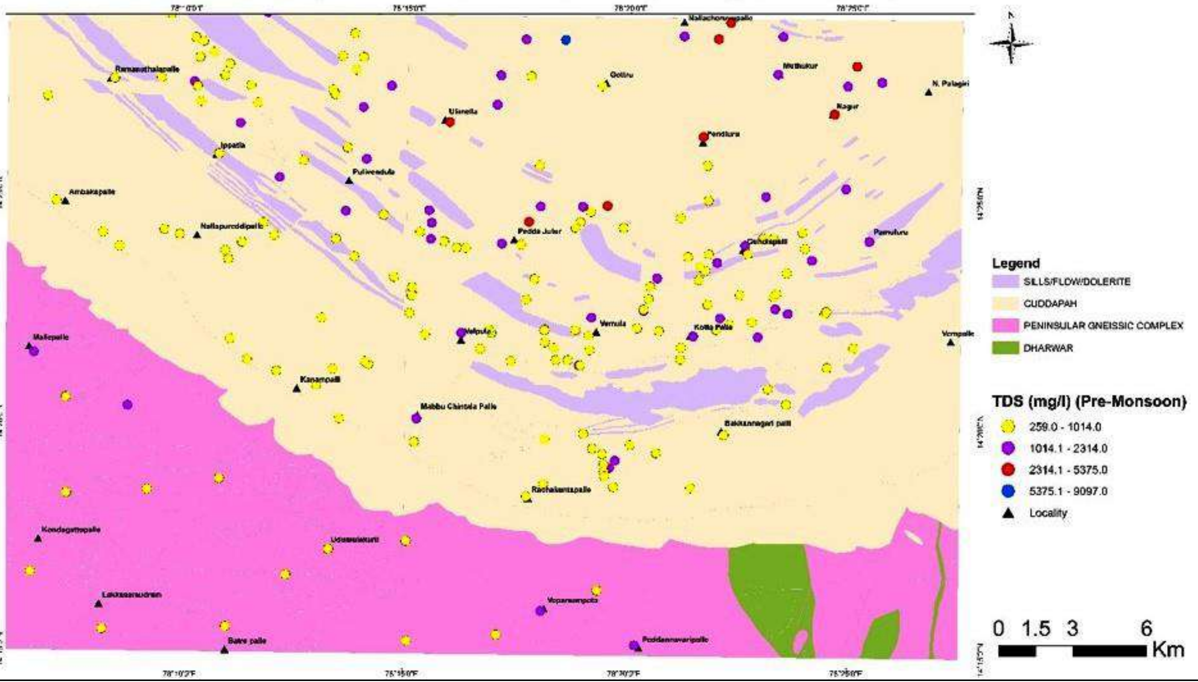
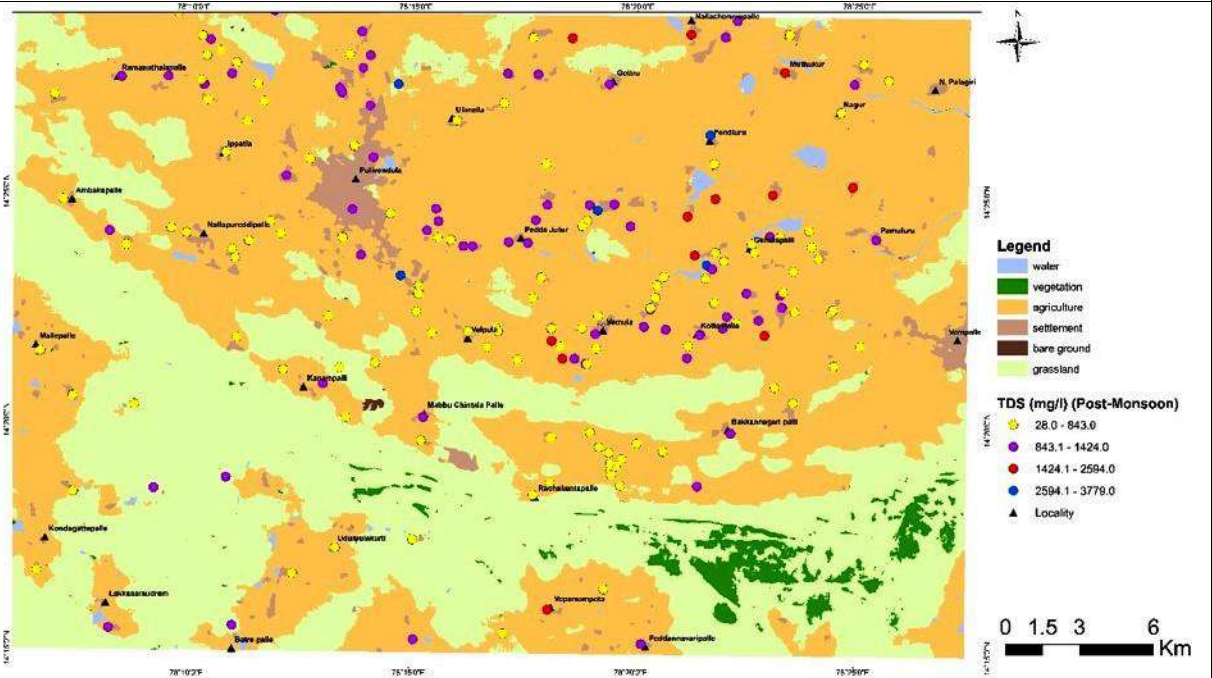


Fig.8.7 Point anomaly map showing TDS (mg/l) concentrations in post-monsoon ground water samples overlying in Landuse-Landcover map of study area of the study area, Parts of Y.S.R. Kadapa and Anantapur districts



Total Hardness (TH): Hardness in water is caused by certain salts held in solution. The most common salts are carbonates, fluorides and sulphates of calcium and magnesium. The hardness in water is derived from the solution of carbon dioxide released by bacterial action in the soil, in percolating rain water (S.K. Naget.al,2013). The concentration of total hardness of the water in the study area varies from **100 mg/L** to **4000 mg/L** with an average value of **485.94 mg/L** in **pre monsoon** and from **25 mg/L** to **1400 mg/L** with an average value of **446.93 mg/L** in **post monsoon** (Table 8.1). Higher TH values in 2 nos. of water samples during pre-monsoon are falling in the agricultural land and over Tadpatri shale of Cuddapah Supergroup in the northeast part of the study area, whereas 10 nos. of water samples during post-monsoon shows higher TH values falling over Tadpatri shale of Cuddapah Supergroup in the agricultural land (Fig.8.8-8.9). The hardness of water is varying from soft to slightly moderate in nature. (Sawyer and McCarty 1967).

Fig.8.8 Point anomaly map showing Total Hardness (mg/l) concentrations in pre-monsoon ground water samples overlying in Geological map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts

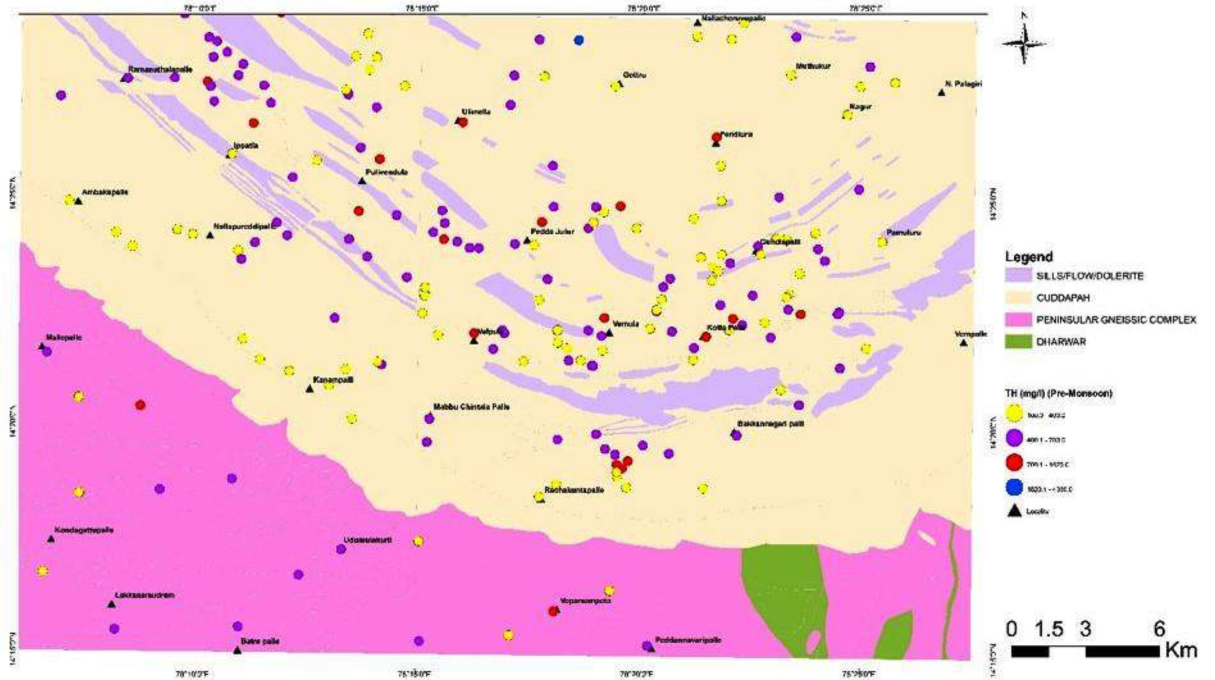
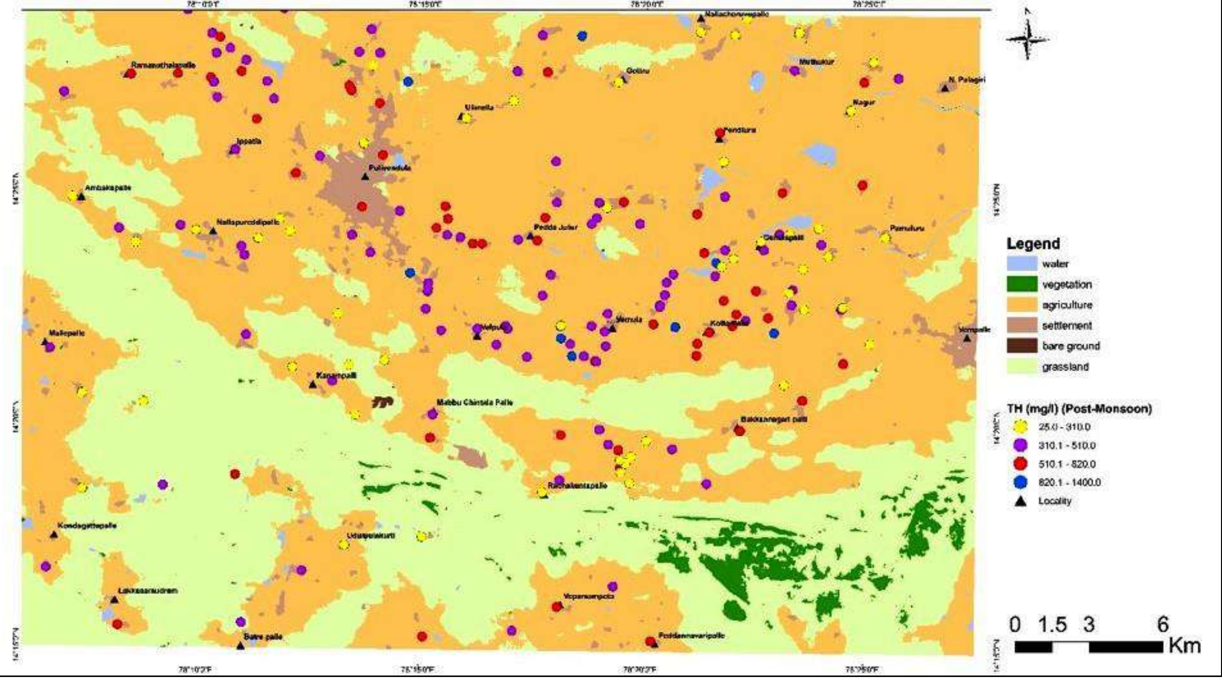


Fig.8.9 Point anomaly map showing Total Hardness (mg/l) concentrations in post-monsoon ground water samples overlying in Landuse- Land cover map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts



Alkalinity: Alkalinity is a measure of water's ability to neutralize acids or resist changes that cause acidity, maintaining a stable pH. Titration is used to measure the alkalinity of a water sample, and water with a pH of 8 or higher is considered alkaline. Soils and geology have the biggest influence on water pH and alkalinity.

Fig.8.10 Point anomaly map showing Total Alkaliity (mg/l) concentrations in pre-monsoon ground water samples overlying in Geological map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts

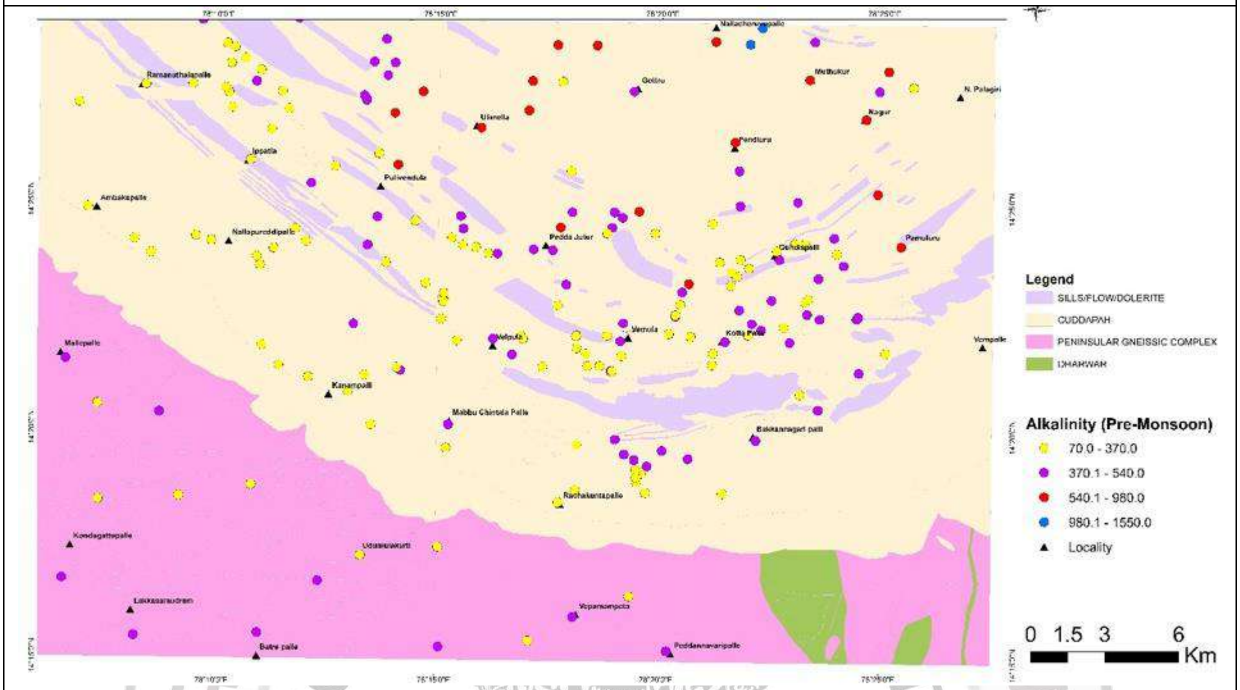
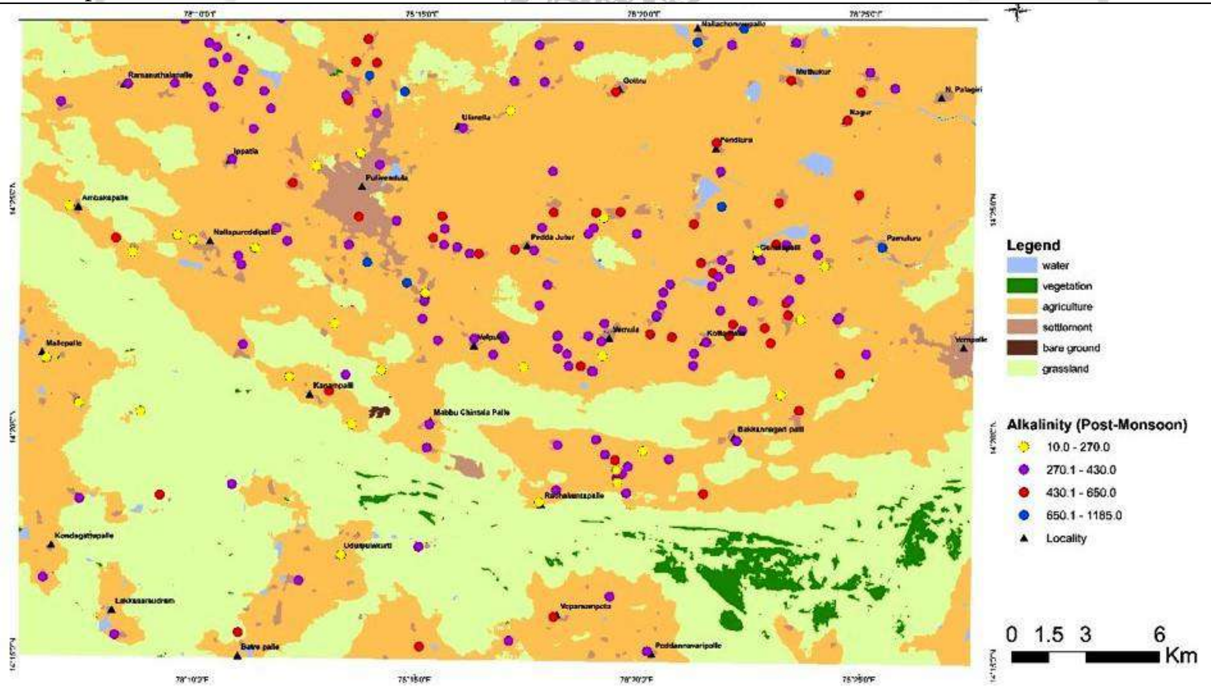


Fig.8.11 Point anomaly map showing Total Alkaliity (mg/l) concentrations in post-monsoon ground water samples overlying in Landuse-Landcover map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts



There are numerous ways to increase water's pH depending on the application and use point. Alkalinity is important for the health and welfare of ecosystems, marine life, and humans. Alkalinity in the water samples varies from 70 to 1550 with an average of 402.99 in pre monsoon and 10 and 1185 with an average of 392.70 in post monsoon (Table 8.1). Higher alkalinity values in 2 nos. of water samples during pre-monsoon are falling in the agricultural land and over Tadpatri shale of Cuddapah Supergroup in the northeast part of the study area, whereas 9 nos. of water samples during post-monsoon shows higher alkalinity values falling over Tadpatri shale of Cuddapah Supergroup in the agricultural land in a scattered manner (Fig.8.10-8.11).

Turbidity (NTU): Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, very tiny inorganic and organic matter, algae, dissolved coloured organic compounds, and plankton and other microscopic organisms. Turbidity makes water cloudy or opaque. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, the causes of high turbidity can promote regrowth of pathogens in the water, leading to waterborne disease outbreaks, which have caused significant cases of intestinal sickness.

Fig.8.12 Point anomaly map showing Turbidity (mg/l) concentrations in pre-monsoon ground water samples overlying in Geological map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts

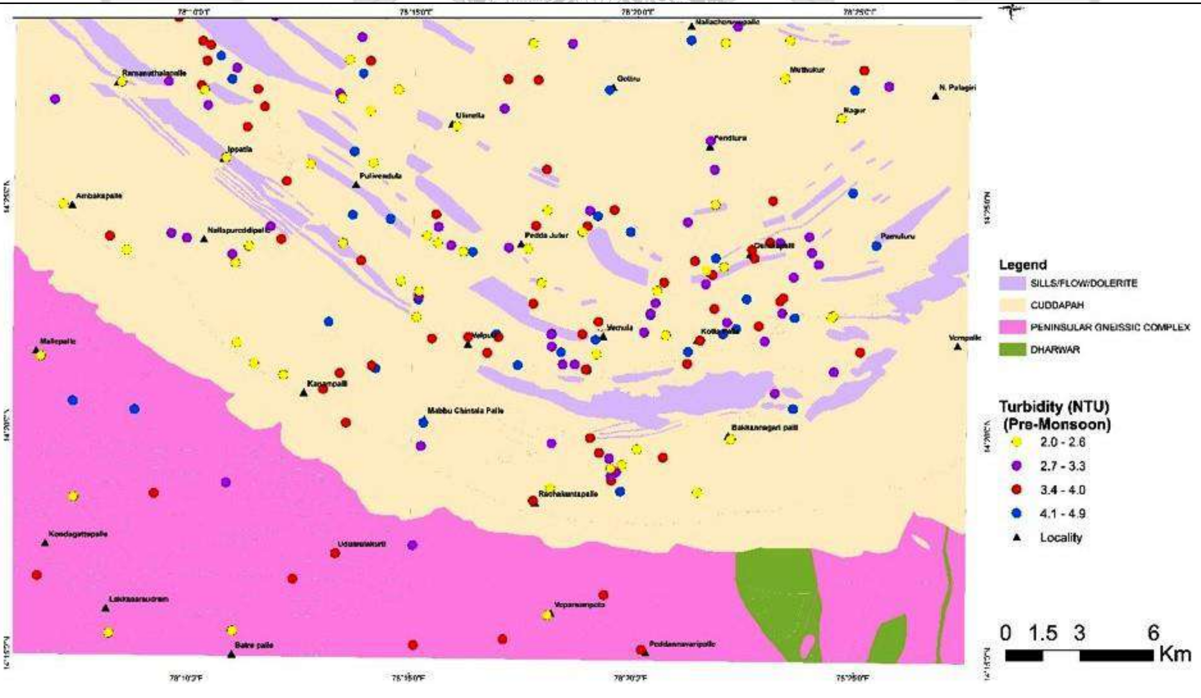
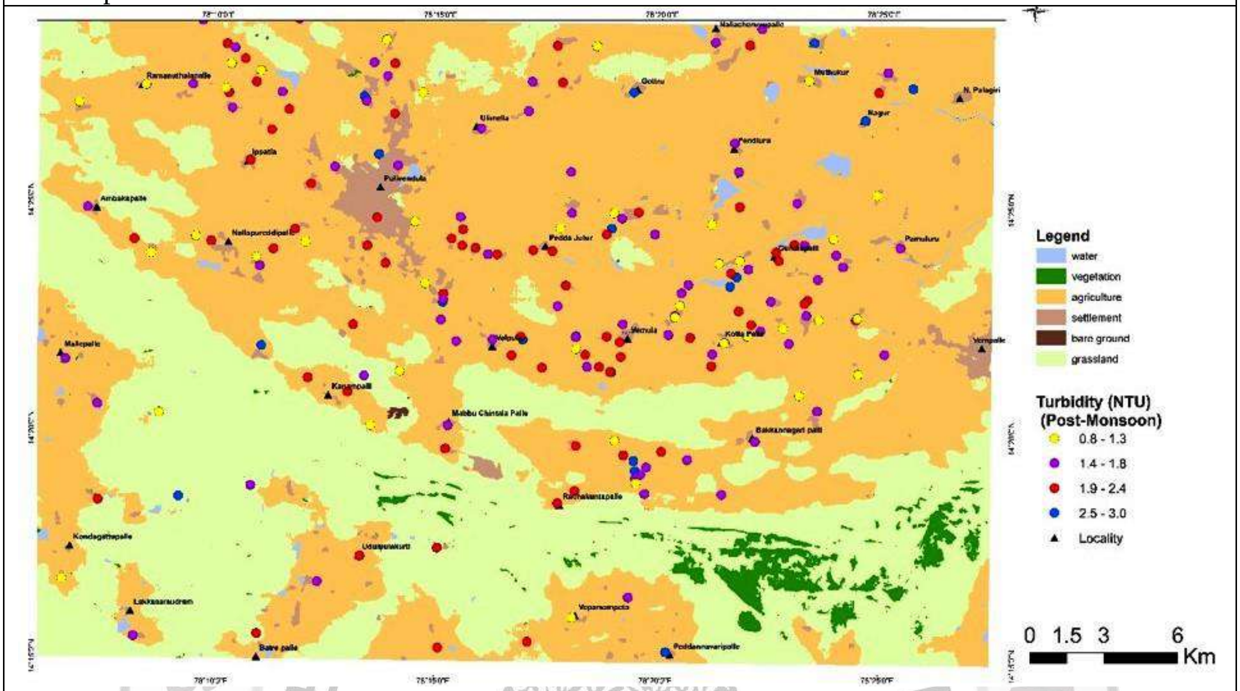


Fig.8.13 Point anomaly map showing Turbidity (mg/l) concentrations in post-monsoon ground water samples overlying in Landuse-Landcover map of the study area, Parts of Y.S.R. Kadapa and Anantapur districts



Turbidity in the water samples varies from 2 NTU to 4.9 NTU with an average of 3.29 NTU in pre monsoon and 0.8 NTU and 3 NTU with an average of 1.80 NTU in post monsoon (Table 8.1). Higher turbidity values in 15 nos. of water samples during pre-monsoon(Fig.8.12-8.13). PGC-II in a scattered manner, whereas 32 nos. of water samples during post-monsoon shows higher turbidity values falling over Tadpatri shale of Cuddapah Supergroup and PGC-II in the agricultural and grass land in a scattered manner.

Calcium (Ca^{2+}): Calcium is the most abundant of the alkaline-earth metals and is a major constituent of many common rock minerals. It is very important for human cell physiology and bones. About 95 % of calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases. According to BIS (2012) standards, acceptable range in drinking water is 75 mg/l. The concentration of calcium of water in study area varied from 8.02 mg/L to 420.84 mg/L with an average value of 56.73 mg/L in pre monsoon and from 2 mg/L to 160.32 mg/L with an average value of 66.84 mg/L in post monsoon (Table 8.1). Higher calcium value in 1 no. of water sample during pre-monsoon is falling in the agricultural land and over Tadpatri shale of Cuddapah Supergroup in the northeast part of the study area, whereas 29 nos. of water samples during post-monsoon shows higher calcium values falling over Tadpatri shale of Cuddapah Supergroup and PGC-