CHAPTER 5

Summary and Conclusions
5.1 SUMMARY

The main objectives of this study are to characterise the rock magnetic properties of lateritic soil profiles developed under *tropical high rainfall conditions*, to determine the spatial variability of soil magnetic properties, to examine the relationship between soil-forming factors (topography, geology and organic matter content) and magnetic parameters in a typical lateritic terrain, to determine the effect of monsoons on the magnetic properties of lateritic soils and to verify the influence of pollution on magnetic property of soils. Surface and sub-surface soil samples were collected from several locations in Kasaragod District in the northern most part of Kerala State, India. Sampling stations were so chosen that they were apparently not disturbed or not affected by anthropogenic activities (except in the case of pollution exposed soil profile). Mineral magnetic analysis was carried out for all the soil samples whereas pH and electrical conductivity (EC), citrate-bicarbonate-dithionite (CBD) treatment, particle size analysis, organic carbon analysis and scanning electron microscope-energy dispersive spectroscopic (SEM-EDS) studies were carried out on selected soil samples.

In order to determine the influence of topography on the mineral magnetic properties of lateritic soils, ten soil profiles developed on a similar lithology (charnockite) and under similar climate were investigated. Soil profiles may be divided into two or three zones based on variations in magnetic parameters. Most of the profiles display a similar trend with relatively low values for concentration-dependent parameters and relatively high $\chi_{fd}$ % values and low $\chi_{fd}$, S-ratio and high $\chi_{ARM}/SIRM$ values in the lower zone. Relatively low $\chi_{fd}$ % values and high $\chi_{fd}$, S-ratio and low $\chi_{ARM}/SIRM$ values are documented at the top of the profiles. Concentration-dependent parameters exhibit a general increase upwards in the lower zone. CBD data also indicate the relatively high content of pedogenic magnetite in the lower zones and a relatively low content in
the upper zone. The lower zones are characterised by relatively high clay and low sand contents and the upper zones by low clay and high sand contents. Aribail, Miyapadavu, Uliyathadka, Cherupanathady, Mundott and Kundamkuzhy profiles are characterised by an upward increasing trend of concentration-dependent parameters in Zone 1 where as Panjikallu, Thekkilaparambu, Devalokam and Karichery profiles display a decreasing trend. The SEM-EDS studies on magnetic extracts from soil samples confirm the presence of haematite, titanomagnetite and magnetite/maghemite.

In order to detect the influence of parent rock lithology on the magnetic parameters of lateritic soils, four soil profiles were investigated that were developed on four different rock types, viz., charnockite, hornblende-biotite gneiss, quartzo-feldspathic gneiss and sandstone. The general trends of magnetic parameters are almost similar, i.e., low and increasing trend (upwards) of concentration-dependent parameter values in the lower zone; but high and decreasing trend (upwards) of concentration-dependent parameter values in upper zone. The magnetic mineral concentration is the lowest in the profile developed on hornblende-biotite gneiss; it increases from quartzo-feldspathic gneiss to charnockite with the highest in ferruginous sandstone.

The variation in soil magnetic properties of Aribail and Miyapadavu (APP2) soil profiles during pre- and post-monsoon seasons were studied. Values of pH increase in post-monsoon samples in all the three zones as soils tend to get neutralized. However, EC value decreases in the post-monsoon samples of all the three zones. There is a slight decrease in the magnetic mineral concentration of post-monsoon samples in Zones 1 and 2. However, there is an increase in the content of SP grains. The magnetic grain size becomes fine in these two zones. The post-monsoon samples of Zone 3 are characterised by an increase in magnetic mineral concentration, decrease in SP grains, and decrease in magnetic grain size. Magnetically “hard” minerals are also relatively more abundant in
post-monsoon samples of Zone 3. This is further substantiated by CBD data. Most of the samples display a greater decrease in the values after the first step of CBD treatment when compared to pre-monsoon samples. Pedogenic $\chi_{lf}$ values also exhibit an increase in post-monsoon samples. Compared to the Aribail profile, the post-monsoon samples of upper zones in the Miyapadavu profile donot exhibit a decrease in magnetic mineral concentration. Both Zones 1 and 2 exhibit a general increase in magnetic mineral concentration and a decrease in grain size.

In order to study the effect of organic matter on pedogenesis, organic carbon analysis was carried out on five soil profiles (Aribail, Miyapadavu, Uliyathadka, Mundott and Narampady). The organic carbon content as well as concentration-dependent magnetic parameters ($\chi_{lf}$, $\chi_{fd}$ and IRM’s and SIRM) exhibit a general increase towards the profile top. Hence, it may be inferred that increased organic matter content enhances the pedogenic processes at the profile-top with a greater production of pedogenic magnetite.

When compared with temperate soils, the tropical lateritic profiles do not exhibit significant magnetic enhancement at the profile-top. Temperate soils exhibit a drastic increase in susceptibility values at the profile-top. Instead of a sudden increase in magnetic parameter values in the top few centimetres of soil profile, lateritic soil profiles display a magnetically enhanced zone. The magnitude of $\chi_{fd}$ and other concentration-dependent magnetic parameters is much high when compared to temperate soils. The magnetic grain size, however, is remarkably similar to that of temperate soils.

Kundamkuzhy soil profile (APP17) situated on a roadside exhibited remarkable increase in $\chi_{lf}$ and concomitant steep decrease in $\chi_{fd}\%$ values in the 0-70 cm depth. This is
highly significant and points towards the influence of pollution on the magnetic properties of soil profiles.

A pedogenic model for lateritic soils from tropical southern India is proposed based on the results obtained in this study. During lateritisation, parent rocks (like gneiss, charnockites, sandstones) are converted into laterites with the enrichment of iron and aluminium hydroxides and leaching of silica and other constituents. Laterite is ferruginous and consists mainly of magnetically “hard” minerals like haematite/goethite in terms of magnetic mineralogy. These magnetically coarse (MD) grains are converted into fine (SP and SSD) grains during pedogenesis and released to lateritic soils. Pedogenic processes get initiated in the upper layers and proceed downwards. The concentration of pedogenic magnetite (SP and SSD) is relatively high in the upper zones and low in the profile-bottom. Due to the excessively high rainfall in the region, magnetite in the upper layers may undergo reduction and be converted into ferrihydrites, leading to a decrease in the magnetic mineral concentration in the top 10-20 cm of the profile. Illuviation may also operate, transporting the fine grains down the profile.

In order to understand the spatial variability of magnetic parameters, the surface soil samples were grouped into two clusters: Cluster 1 (surface soil samples from the northern part of Kasaragod District), and Cluster 2 (surface soil samples from the central part of Kasaragod District). In cluster 1, where parent rock lithology is similar, the magnetic properties of surface soils are mainly controlled by slope whereas in cluster 2 they are controlled mainly by lithological variations. The magnetic mineral concentration, grain size and mineralogy vary considerably in surface soils. The concentration of pedogenic (SP) magnetite increases from NW to SE and east in the northern part of Kasaragod District. Magnetic mineralogy also displays spatial variations, with high contributions from magnetically “hard” minerals in the NW part but from
magnetically “soft” minerals in the SE. Magnetic grain size does not exhibit much spatial variation; it is relatively fine in Miyapadavu samples. The large spatial variability of magnetic properties within a small area may be due to the geographical location of the sampling sites. As all the four sampling sites are located in slightly elevated areas, they are vulnerable to soil erosion. As the parent rock, climate, soil type and vegetation are almost identical in all the four locations, the variations in soil magnetic properties may be attributed to soil erosion.

In central part of KasaragodDistrict (Cluster 2), $\chi_{lf}$ and $\chi_{fd}$ values display a similar trend with high values documented in the central (Shantinagar) and south-western part of the study area (Mundott and Cherupanathady). The concentration of pedogenic SP magnetite is relatively high in the central and SW parts. Both $\chi_{lf}$ and $\chi_{fd}$ values are relatively low in the eastern and western portions of the study area. The high $\chi_{lf}$ values in Shanthinagar may be due to the influence of parent rock lithology (quartzo-feldspathic gneiss). Magnetic mineralogy also displays spatial variations, with high contributions from magnetically “hard” minerals centred on Narampady and Uliyathadka areas. Magnetically “soft” minerals are predominant in the southern portion of the study area. Magnetic grain size does not exhibit much spatial variation; it is relatively fine in Karichery, Panjikallu and Mundott areas. In other sampling sites, the magnetic grain size is relatively coarse.

A comparison of the pre- and post-monsoon values for magnetic parameters of surface soil samples reveals that there is a significant increase in the magnetic parameter values in the post-monsoon samples. The top-soil magnetic susceptibility values are significantly higher than those for temperate soils.
5.2 CONCLUSIONS

- The general trends of concentration-dependent magnetic parameters in lateritic soil profiles are remarkably similar: either low values at the profile bottom and a gradual increase up to a certain depth and then a decrease; or a steady increase from the profile-bottom to the top of the profile.

- Topography has only a minor influence on the general trend of magnetic parameters in lateritic soil profiles probably due to their deeply weathered nature. However, topography may influence the absolute values of magnetic parameters among different profiles. The profiles situated near the base of lateritic hills exhibit relatively higher concentrations of magnetic minerals and pedogenic magnetite (in the upper zones) compared to those profiles situated on hill slopes or lateritic upland.

- Lithology plays a major role in determining the magnetic properties of the resulting lateritic soils. However, the general trends of magnetic parameters in a soil profile are notably similar, with variation only in the absolute values. The magnetic mineral concentration is the lowest in the profile developed on hornblende-biotite gneiss; it increases from quartz-feldspathic gneiss to charnockite with highest in ferruginous sandstone-hosted soil profiles. High initial Fe concentration in parent rock results in high magnetic mineral concentration in soils developed on them.

- During post-monsoon season, the concentration of fine grained, magnetically “soft” pedogenic magnetite (SP) grains increases, resulting in the enhancement of magnetic parameters. The pedogenic SP grains are relatively high in the bottom zone due to illuviation. However, its absolute concentration is high at the profile-top as pedogenic processes are initiated at the soil surface.
A high content of organic matter at the profile-top enhances the pedogenesis and hence the production of pedogenic magnetite.

When compared with temperate soils, the tropical lateritic profiles do not exhibit significant magnetic enhancement. Instead of a drastic increase in magnetic parameters in the top few centimetres of the soil profile, a magnetically enhanced zone is documented at the top of the profile. Even in this magnetically enhanced zone with a higher content of SP grains, the upper few centimetres exhibit a decrease of values in some profiles. This may be due to iron reduction due to excessively high rainfall or top-soil erosion. The magnetic grain size, however, is remarkably similar to that of temperate soils.

A pedogenic model for the lateritic soils developed under tropical climatic conditions is proposed based on the results obtained in this study: During lateritisation, the parent rock is converted to laterite with the enrichment of iron and aluminium hydroxides and leaching of silica and other mobile constituents. This laterite is ferruginous, and the magnetic mineralogy dominated by magnetically “hard” minerals like haematite and goethite. The magnetically coarse (MD) grains are converted into fine (SP and SSD) grains during pedogenesis and released to lateritic soils. Rocks with a high initial high Fe concentration give rise to magnetically strong profiles with a higher pedogenic magnetite content and vice versa. Illuviation may transport the fine grained SP grains along with clay particles to the bottom of the profile, resulting in a relative increase in the proportion of SP grains although their absolute concentration is low.

The spatial distribution of magnetic parameters is governed principally by topography in a smaller region with similar parent rock lithology. Areas with
moderate slopes exhibit a generally low magnetic mineral concentration and pedogenic magnetite content. Areas with a gentle to flat topography exhibit a higher magnetic mineral concentration and pedogenic magnetite content. In a larger area, the spatial distribution of magnetic mineral concentration, grain size and mineralogy is governed principally by the parent rock lithology. Soils developed over rocks with a high initial Fe concentration exhibit a high magnetic mineral concentration.

- There is a significant increase in the production of pedogenic magnetite in the post-monsoon samples.
- Top-soil magnetic susceptibility for lateritic soils from tropical regions is notably higher than that of temperate soils.
- The soil profile influenced by vehicular emission exhibits magnetic properties notably different from unpolluted soil profiles with maximum values for magnetic susceptibility, lowest SP grain proportion and coarse magnetic grain size (MD).
References