CHAPTER I
INTRODUCTION

Soil formation is the product of physical and chemical weathering of rocks under the influence of five main factors, of which climatic and biotic factors are the most important. Soil profile, the succession of soil horizons down to the parent material, expresses the results of the soil forming processes acting on the given parent material. Profile study is important because every soil property has its own vertical distribution pattern or specific "depth function". In fact, the three dimensional soil sample i.e., pedon is taken to be the unit of soil study.

Rock weathering is the process by which the earth's surface gains in specific surface area through the continuous reduction of large particles to smaller and smaller particles or by the decomposition of primary minerals with the formation of clay size minerals. These fine particles may then be carried away by wind, water or ice, and redeposited elsewhere as loess, alluvium or boulder clay or, these on or near the surface of these deposits may be carried into lower layers with the percolating water. The mineral particles can also suffer chemical decomposition through solvent action of water itself and through the reactions between the surface of soil particles and suspended materials in water or
dissolved substances such as oxygen, carbon-dioxide, alkalies and organic acids. The fate of these products of decomposition depends mainly on the rate of water movement through the soil. The greater the amount of downward leaching, the higher the proportions of the products of weathering that are removed from the zone, in which they were formed and either redeposited in the lower layers of the soil or else carried with the percolating water into the ground water and ultimately into the rivers. Not all the soluble products of weathering are, however, immediately transported but some are redeposited lower down the soil and some recombine, either where they have been produced or further down in the soil, to form secondary minerals, such as clay, which are more or less resistant to further weathering under the prevailing conditions.

Weathering processes thus tend to develop a sequence of horizons within the zone of alteration. The horizons show differences in the degree of breakdown of parent material, in relative abundance of secondary mineral components, in particle size distribution, in organic material, in soil reaction and in character of alkali and alkaline earth contents. Vertical movement of water causes the translocation of soil constituents thereby developing the sequence of varying horizons. An apparent difference in the degree of degradation of parent material or rather maturity can be inferred from the migration of colloidal clay particles within the soil and the distribution of clay minerals in the successive horizons of a soil pedon. Differences
in the nature and the relative abundances of secondary clay minerals will be reflected in the differences in cation exchange capacity as well as physical properties of the soil material.

Among the five major factors largely controlling the development of soil, parent material and climate take the prominent role. Parent material may thus be regarded as the initial stage in the development of soil. From an overall standpoint, climate is perhaps the most important factor. It includes all the conditions from which it is made up such as temperature, rainfall and wind which exert profound influence on the kinetics of soil development. The other important factor is time. So soil is directly a function of climate and this climatic factor imparts to the zonal character of the world group of soil classification. Along with these, topography is another powerful factor in the development of soil, which may hasten or delay the work of climatic forces. This factor encourages the formation of shallow or deep soils within a given locality giving rise to catenary group of soils. Variations in chemical weathering might be expected to arise between these catenary groups because of the drainage factor.

In the tropics under different climatic conditions, different types of soils are formed. India is a subcontinent with a great diversity of climate, topography and physiography. Intensity of rainfall is different and temperature also varies considerably. Vegetation and parent materials are also of different types. Large varieties of soils have, therefore, been formed by the interaction of these varying factors. Of these, red soils and laterite
and lateritic soils constitute important groups, covering about 5,98,000 sq. km area.

Red soil profiles develop under humid conditions and high temperature. The humidity increases with the mean annual temperature and as a result of these extreme climatic conditions, chemical weathering goes on very rapidly and completely. The original characteristics of the parent rock are soon destroyed, and the rock minerals are broken down into simple components such as free silica, alumina, ferric oxides and bases. Under humid conditions, the more soluble components are readily washed out and thus red soils are characterised by a marked simplicity in their chemical composition. The main variations in chemical composition are, therefore, found in the relative quantities of the component parts viz., silica, alumina and iron oxides of the complex silicates. When the silicates are broken down by weathering, the sesquioxides and the silica are able to move independently throughout the soil profile and silica : alumina or silica : sesquioxide ratio, therefore, assumes a particular significance in the characterisation of these soils. The intense chemical weathering associated with hot and humid condition leads to the formation of much clay and quartz and hence the majority of red soils are texturally classified as loams.

Red soils are generally poor in nitrogen, available phosphorus, humus content and plant nutrients and are light textured with porous and friable structure. They do not contain honeycomb structure of precipitated iron oxides but patches of
sesquioxide are present throughout the profile. Clay minerals present are generally hydrous oxide types mixed with kaolinite or illite. Low silica : sesquioxide ratio of the clay fractions and soils, low cation exchange capacity, low base saturation, high amounts of iron and aluminium, low activity of clay, low pH, low content of primary minerals, low content of soluble constituents, light texture, a high degree of aggregate stability, red colour are the main characteristics of these soils.

Laterite soils are characterised by the presence of free alumina and iron oxides and also by very low silica:sesquioxide ratio. By the action of high temperature organic matter is intensively weathered to the end products of mineralisation i.e., CO₂ followed by release of bases rendering the pH of the soil almost neutral. This pH status facilitates the precipitation of iron, aluminium, manganese, titanium and solubilisation and release of silica. Soil is thus an independent dynamic body of nature that acquires properties in accordance with the forces which act upon it. When weathering and soil forming processes approach a reasonable static condition a second process develops in which stable aggregates of secondary minerals are formed. Their development produces a reduction of specific surface area and effect produces a mineral system which is stable to the processes of rock and mineral weathering. Examples of these aggregates are concretions of various minerals and iron oxide layers in the soil. They are stable units in the soil system. Seven processes of formation of these secondary mineral units
have been identified. They are as follows:

(a) Evaporation, (b) Replacement, (c) Deposition and precipitation (d) Mineral degradation
(e) Ionic migration (f) Dehydration (g) Induration

The processes are not necessarily independent of each other but are often interrelated.

The parent material, one of the soil forming factors, exerts some control on the clay minerals that form, because weathering releases constituents essential to the formation of various clay. Rocks and minerals of varying composition weathering in the same environment can produce different clay minerals. Acid igneous rocks such as granite and granite-gneiss, low in bases, usually favour the formation of kaolinite clay mineral whereas rocks like basalt, gabbro, high in bases, favour the formation of montmorillonite.

The rate of clay mineral formation depends on the adsorption and condensation of the reactants. Any condition which promotes condensation and adsorption would accelerate clay mineral formation, and conditions hindering the adsorption and condensation retard the formation of clay mineral. Thus it follows that the nature and the amount of clay minerals in different horizons of soil profile would give us information on the extent of breakdown of minerals due to weathering as also recombination of the product of weathering.
As the physical and chemical properties of the soil and to a large degree the soil behaviour are determined by the nature and contents of these clay minerals it is essential that any soil investigation either for agriculture, irrigation or engineering must include a study of the mineralogical composition of the clay fraction and their electrochemical properties. Such studies not only bring out the genesis and the mode of formation of different soils, but also indicate the mechanism of nutrient uptake by plants, fixation of nutrients in soil, soil-water relationship, micronutrient absorption in soil, all of which are essential in planning agricultural development in any area. It is equally essential to know the process of formation, evolution of the different horizons and the degree of development of the profile in terms of mineralogical, chemical, physical and morphological changes that occur in the transformation of the parent material into the soil material — in short the genesis of the soil.

A brief review of the previous work on the genesis of laterite and red soils, particularly to those related to the work recorded in this thesis, has been presented in the chapter that follows.