STUDIES ON SOILS OF ANDAMAN AND NICOBAR ISLANDS

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BY

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This is to certify that Sri C. J. Thampi, M.Sc.(Ag) has been working under my supervision since 1974. I am forwarding his thesis entitled "STUDIES ON SOILS OF ANDAMAN AND NICOBAR ISLANDS" being submitted for Ph.D. degree in this University.

Sri Thampi has fulfilled all the requirements according to the rules of this University regarding the investigations embodied in his thesis.

Assistance received during the course of this investigation and sources of literature have been duly acknowledged.

(Asit Kumar Mukhopadhyaya)

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(C. J. THAMPI)

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A B S T R A C T

Investigation on nine associated soils occurring in three toposequence in different locations of the Andaman and Nicobar Islands reveals that the development of the soils have taken place on more or less uniform parent material of sedimentary origin and similar environmental conditions of this oceanic region. Moisture regime and topography play a vital role in the formation of these soils. Soils are relatively high in montmorillonite mineral and is in association with illite and kaolinite. No laterisation has been observed in these Islands and the soils are comparatively immature. pH of the soils appears to be relatively low in comparison with high base saturation which may be due to the high content of magnesium in the exchange complex.

Moisture regime of different soils of the toposequence have been studied and there is an increasing trend from upper member to the lower ones of the catenary association. Run off and soil loss have been found high in different locations of associated soils and needs effective soil conservation measures and other soil management practices for preserving the productive potential of the soil on sustained basis. Agricultural potentiality of different soils were studied in relation to land capability classification and found the soils fall within Class II, III and IV from lower member to the upper member of the catena in the sequences. Soils have been classified under U.S.D.A. classification. A comprehensive system, 7th approximation and are in the order

'Alfisol'. The study of the associated soil facilitate interpretation, classification, terrain analysis for soil survey in the preparation of soil and land use map.

SCOPE AND OBJECTIVES

SCOPE AND OBJECTIVE

Much information is not available regarding the systematic study and land use classification of the associated soils in the Indian sub-continent particularly in the Andaman and Nicobar Islands. Hence, it was considered worthwhile to study such associated soils of the Andaman and Nicobar Islands. The knowledge derived from these studies shall be of utility for soil survey, classification, soil management and crop production of the areas (Plate 1).

The sequences of soils of about the same age, derived from similar parent material and occurring under similar climatic conditions, but having different characteristics due to variation in relief and drainage has been reported in this oceanic region of Andaman and Nicobar Islands (Raychaudhury et al., 1972; Thampi, 1960; Thampi, 1961). The associated soils present diverse characteristics. Very little information with regard to physical, chemical and minerological characteristics of the soil sequences are available.

Climate

The climate is tropical, warm but tempered by pleasant sea breeze. These islands are situated in the full sweep of the monsoon and rainfall is heavy but varies from place to place. The rainfall ranges between 2750 mm and 3250 mm annually. Rain occurs practically over nine months. The chief rainy months are May to December which account for about 95 per cent of the annual

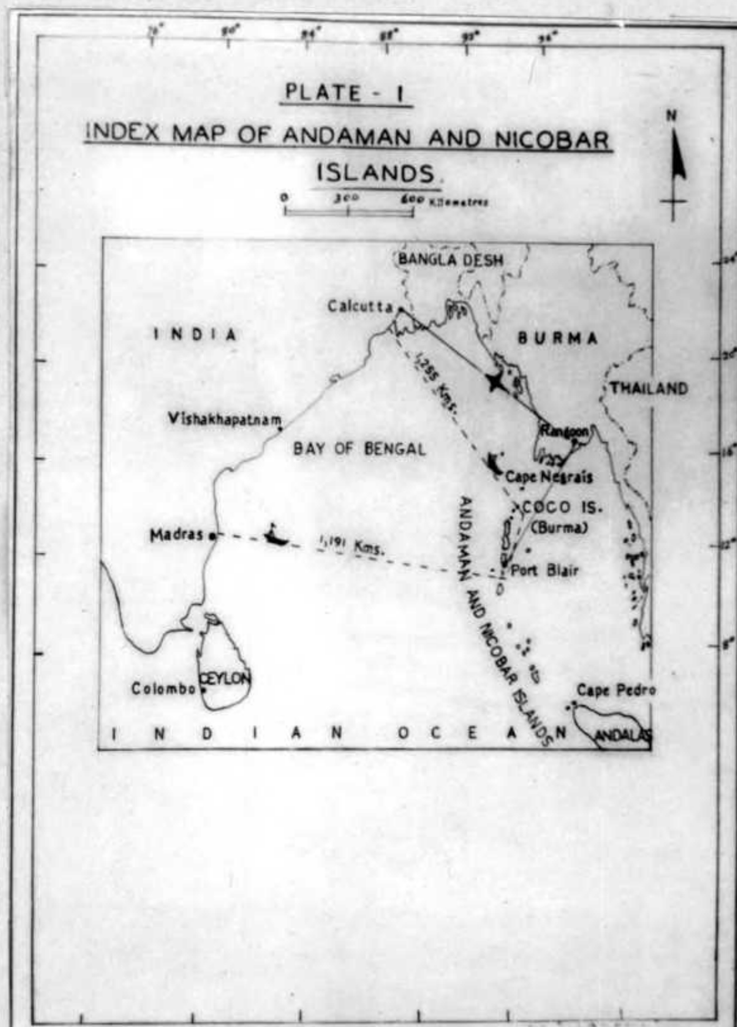


PLATE - I
INDEX MAP OF ANDAMAN AND NICOBAR ISLANDS.
0 300 600 Kilometres
N
BANGLA DESH
Calcutta
INDIA
BURMA
THAILAND
1255 Kms.
Vishakhapatnam
Rangoon
BAY OF BENGAL
Cape Negrais
COCO IS.
(Burma)
Madras
1,191 Kms.
Port Blair
ANDAMAN AND NICOBAR ISLANDS
CEYLON
Colombo
Cape Pedro
ANDALAS
INDIAN OCEAN

rainfall. June is the rainiest month of the year accounting for 18 to 20 per cent of the total annual rainfall and February and March are the months with the least amount of rain (about 1 per cent). In the months of May to October there is no month with less than 10 rainy days of 10 per cent or more. At Port Blair every 2 out of 3 days is a rainy day of 10 per cent or more during these months.

Study of annual precipitation data of different parts of these Islands by applying a non parametric test for trend has shown that there is no tendency to have progressively increasing or decreasing amounts of rain fall which fluctuates year after year in each individual case. In soil and water relationship dealing with its use and removal from soil, expected recurrence period and duration are of paramount importance in a place like Andaman and Nicobar Islands whose economy and well being of the people are based on agriculture. In a series of annual precipitation records there is very little evidence of progressive increase or decrease, the characteristics being the oscillations with no regular period and amplitude. These might be due to the eccentric behaviour of rainfall intensities over years or there might be some basic periodic pattern over which is superimposed the random fluctuations. It is further observed that precipitation intensities are entirely erraticand unpredictable. This may be due to so many atmospheric agencies affecting the precipitation over any region that although their individual effects may be regular and periodic, the combined effect may not be so. Maximum.

intensity of rain fall per hour recorded at Port Blair is 60.2 mm.

The annual variation in temperature in these islands with their maritime climate is small. The annual mean maximum temperature for the year in the Island is from 29°C to 31°C, mean minimum temperature from 23°C to 25°C and mean temperature from 26°C to 28°C. April is generally the warmest month with a mean maximum temperature 31°C at Port Blair and Table Islands and 32°C at Car Nicobar and Noncowrie. The lowest mean temperature, however, does not seem to occur in a particular month. There is a tendency for this to occur in February in the northern half of the Islands and during October or November in the southern half. The highest and the lowest temperatures ever recorded in the islands are 37°C and 17°C respectively. Lower, occurs in the middle of the south-west monsoon period in the northern half of the islands and during December or January in the southern half.

Humidity is high throughout the year, being highest in the south-west monsoon season when the average reaches 90 per cent. On individual days the atmosphere may be saturated. The lowest humidity occurs in the months of December to February. The annual variation is about 15 per cent. Clouding in all the months is more than three tenths of sky and is maximum in the monsoon months. The islands are generally windy where in July the average wind speed is 16 m.p.h. During November to February the winds are mainly between north and east, while in the south-west monsoon months strong westerly or south westerly winds predominate. March and April are transition months with westerly winds increasing and in May 70 per cent of the winds are westerly. Monthwise distribution of rainfall, temperature and humidity is given in the Annexure I. Though the islands receive high precipitation, it is often ill-distributed and causes crop damage due to continued dry spell during kharif cropping season. This calls for effective measures for minor irrigation schemes and water harvesting structures to utilize the excess water that drains into the sea during monsoon.

Drainage and Water Supply

The steep slopes and medium to fine textured soils favour rapid drainage in spite of heavy rainfall. The short distance to the sea from across the main north-south line of the hills and the narrow catchment areas in them have resulted in numerous small seasonal streams, but no major rivers and only very few perennial streams. In fact, fresh water supply all round the year is comparatively scarce in many parts of the Andamans. In the Islands of Great Nicobar, Little Nicobar and Katchal, however, there are few perennial streams. Even so, in no island is the supply of fresh water copious enough to support any large demand for it. In fact, this adverse factor inhibits the fuller processing or utilisation locally of some of the natural resources of the Islands.

Physiography

The configuration of the ground is generally rough cut up by ranges of hills enclosing narrow valleys. The land in the Andamans often rises steep off the sea, clearly suggesting to their being the visible ridges and summits of sunken ranges of mountains. The general direction of the hill ranges is north-south but several spurs and ridges run off the main ranges in all directions. While there are no great elevations, the ranges on the eastern side of the islands are higher than those in the west and the highest point. Saddle peak, in the North Andaman island is 800 m., above sea level. The slopes are moderate to steep, rugged and is susceptible to severe erosive hazard. Level lands are comparatively scarce. Coral formations are seen in many of the locations of Andaman and Nicobar group islands. They often have narrow but long stretches of sandy beaches. Car Nicobar islands is almost level and while all the others include hilly terrain, the highest elevation here is less than 700 m, in Great Nicobars, in particular the land surface is very irregular, often broken by steep hill ranges and valleys. Physiography of Andaman Islands is presented in Plate 4 and Nicobars in Plate 3.

Geology

Andaman and Nicobar Islands forms one of the most interesting regions of India. These islands are in structural continuity, beneath the sea, with Burma and of the Himalayan system in the north and the West Indies in the south. The chain

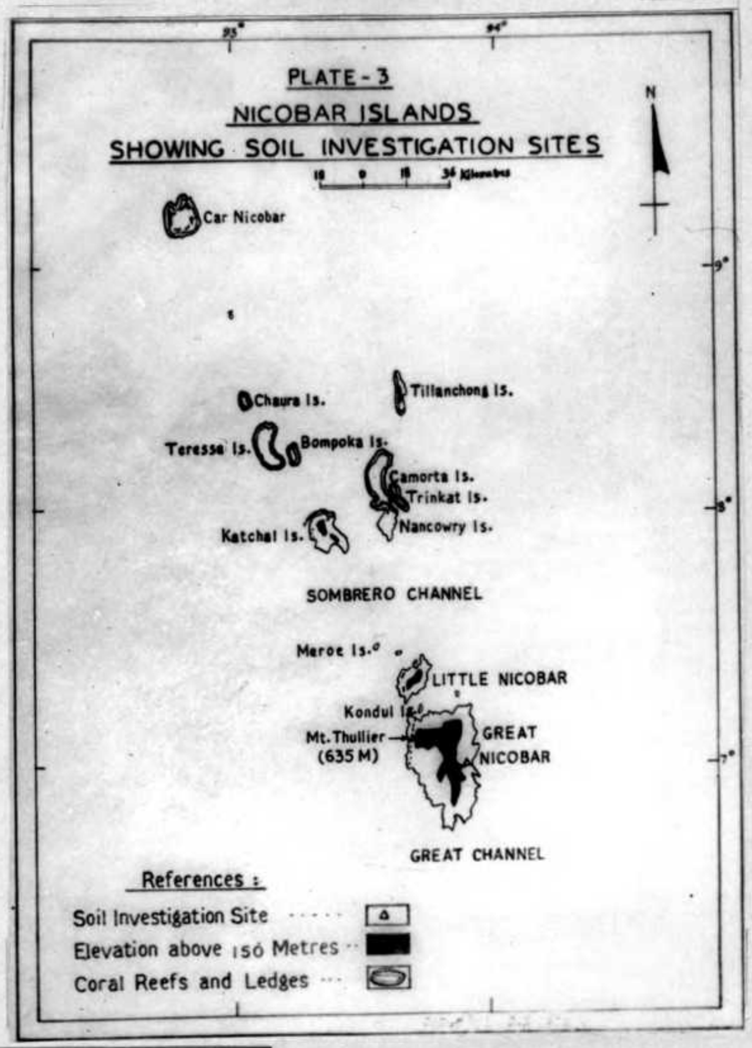


PLATE-3
NICOBAR ISLANDS
SHOWING SOIL INVESTIGATION SITES
Car Nicobar
Chaura Is.
Tillanchong Is.
Teresse Is.
Bompoka Is.
Camorta Is.
Trinkat Is.
Katchal Is.
Nancowry Is.
SOMBRERO CHANNEL
Meroe Is.
LITTLE NICOBAR
Kondul Is.
Mt. Thullier
(635 M)
GREAT
NICOBAR
GREAT CHANNEL
References :
Soil Investigation Site
Elevation above 150 Metres
Coral Reefs and Ledges

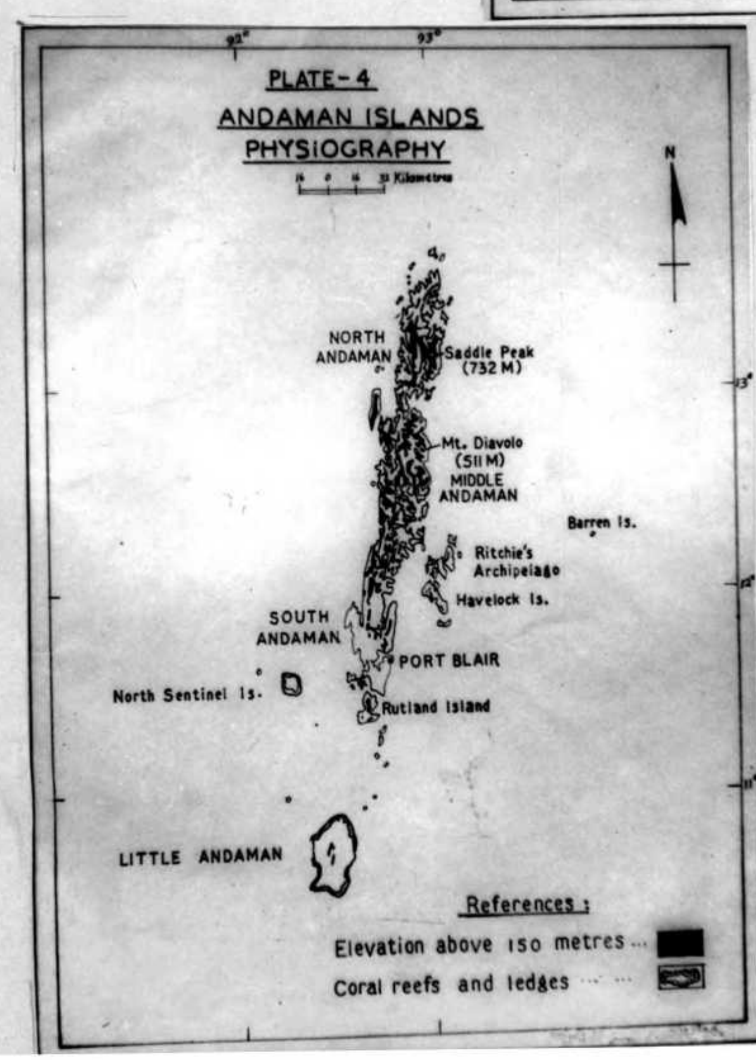


PLATE-4
ANDAMAN ISLANDS
PHYSIOGRAPHY
NORTH
ANDAMAN
Saddle Peak
(732 M)
Mt. Diavolo
(511 M)
MIDDLE
ANDAMAN
Barren Is.
Ritchie's
Archipelago
Havelock Is.
SOUTH
ANDAMAN
PORT BLAIR
North Sentinel Is.
Rutland Island
LITTLE ANDAMAN
References :
Elevation above 150 metres
Coral reefs and ledges

can be separated into two concentric outer areas (western) non volcanic are composed of the major islands of the Andaman and Nicobar, and inner (eastern) volcanic are including barren and Narcondum Islands.

The surveys that have been carried out so far together with the available data make it possible to draw a generalised stratigraphic succession for these islands, as given below with oldest formations at the bottom (G.S.I., 1968).

Quarternary

Alluvium, raised beaches and limestone form recent and sub-recent origin.

Tertiary

Shales of Nicobar group, south Andaman and Ritches Archipelago and limestones and sandstone of Interview island, long island and Ritches Archipelago group, the Andaman flysch group and grits, conglomerates, sandstone and shales of the Andaman group of Miocene and Pliocene period.

Mesozoic

Saddle hill phase (Gableves, trectolites, peridotite, serpentinites, andesites and basalts), limestone (marble), cherts, jaspers and quartzites of cretaceous period.

Older sediments, including jaspers, quartzite and crystalline limestone occur sporadically as xenoliths within igneous rocks, in the main Islands of the Andaman group. The ultrabasic and basic rocks are found over fairly large areas on these islands occupying high grounds like saddle peak in the North Andaman, Sound Peak and Mount Baker in Middle Andaman, the hills south of Port Blair, Rutland and Little Andaman Islands, and in places in Great Nicobar. The ultrabasic rocks occur mainly as lenses within the younger sediments.

The conglomerates and grits occur abundantly in the North and Middle Andaman islands and cover fairly large areas of the south Andaman and Great Nicobar Islands. The flysch group, including sandstone, silt-stone and shale, is the predominating rock type of Andaman and also of Great Nicobar. It also occurs in Kamorta, Katchal and Nancowry islands in the Nicobar group. Sporadic occurrances of such rocks have been noticed in parts of Middle Andaman and the south-western part of North Andaman.

The limestones occur commonly within calcareous sandstone and shales in the Long, Guiter, Interview, Car Nicobar, Rutland Islands and the Ritches Archipelago. Lenticular limestone masses have also been noted in the Mayabundar, Tugapur and Rangat areas of Middle Andaman. The white to greyish white shales occur fairly abundantly in the Ritches Archipelago, Long, Guitar and Sound islands, and in Car Nicobar, Nancowry, Camorta, Trinket and Great Nicobar.

The topography is a reflection of the geology and climate of the island. The rocks are mostly rather soft sedimentary formations such as sandstone, silt stones and clay beds, shales and lime-stone and minor volcanic rocks of basic and ultra basic composition as seen from the above description. The sedimentary formations are highly folded along a nearly N-S axis as well as jointed in a E-W direction. The drainage is largely controlled by the fold direction as well as the joint pattern of the rocks.

Some of the geological specimens collected and their petrographic information are given below :

1. Salenite

Crystallised and transparent variety of Gypsum (CaSo4, $2H_2$)

2. Quartz

Milky white massive quartz.

3. Ferruginous Sandstone

Dark brown, medium grained rock; composed of roughly sorted, rounded to subangular grains of quartz and few felsper grains. The grains are cemented together by ferruginous material, quartz and sericitic matter.

4. Jasper

Reddish mineral; an amorphous and compact variety of silica.

5. Chert

Yellowish brown, greenish hard and compact mineral (variety of chalcedonic silica).

6. Pitchstone

(Weathered rock) The rock is almost entirely composed of dark brown glass, which shows divitrification to some degree. Few irregular veins and pockets of calcite are seen. There are some spherules of isotropic mineral which show crude radial disposition.

7. Pitchstone

(Pitch Black rock) The rock is composed of fairly divitrified dark brown glass studded with microlites of minerals which cannot be clearly distinguished. Abundant minute granules of magnetite are seen distributed throughout. minerals and rarely of palagonitic substance are observed.

8. Rhyolite

(White, weathered rock) Microlites of felspar and some quartz are embedded in the brownish glassy matrix. Felspars range from Alibite to oligoclase and show carlsbad and albite carlsbad twinning.

9. Greywacke

(Grey and slight, weathered rock) Fine grained, grey rock; angular to subangular grains of quartz and some felspars are embedded in the matrix composed of dark brown argillaceous matter, chlorite, rock fragments and iron oxides, few flakes of mica can be seen. Preferred orientation is exhibited by quartz felspar grains and also by dark argillaceous patches, which seem to be drawn on a direction probably parallel to bedding plane.

10. <u>Ferruginous Sandstone</u>

(With quartz Vein) Weathered ferruginous sandstone, essentially composed of quartz and some feldspar, which is very often serectised. Most grains are sub-angular to rounded and cemented together by dark brown ferruginous material and some silicious matter. The rock is traversed by quartz veins.

11. <u>Greywacke</u>

(Grey, hard and compact rock) Medium grained rock, composed of subangular to angular grains of quartz and some feldspar in a matrix of quartz, serecitic matter rock-fragments minor amounts of mica, and patches of magnetite. Elongation of mineral grains in one direction (which are not well sorted) impart somewhat schistose structure to the rock, contrary to the general nature of angularity in grains, there are a few 'rounded' grains of quartz as well.

These islands constitute the submerged island arc in the north and East Indies in the south. The convexity of this arc is to the west. The islands fall within the earthquake belt of the world. Mud volcanoes are still present in the islands. 'Recent' volcanic activity is discernible in the Barren, the Baratang and the Narcondum islands where hot sulphur springs and mud volcanoes are seen. Laterisation has not been noticed yet in any part of the island.

Vegetation

The Andaman and Nicobar Islands abound in forest wealth. The forest in the Islands may be grouped into five distinct types, viz.,(1) the mangroves, (2) the littoral forests, (3) the deciduous forest, (4) the evergreens and (5) the evergreen hill forests.

1. The mangrove forests

The forests are evergreen, confined to belts subject to tidal action along the coasts and alongside the creeks, on saline low-lying land. The mangrove belts vary in depth from a few meters to several. The main species are Rhizophora murronate, R. conjugata, Bruguira symorrhiza, B. paryificra, Carana obovata, Sonneratia acida, and less commonly Nepa fruticans. These mangrove forests are inundated at regular intervals by the rise and fall of the tides, rendering the soil very soft. Nature's adaptation in the circumstance is a tangled mass of roots that render the areas almost impenetrable. But this feature enable the mangroves to stabilize themselves in the soft and so fulfil the important function of preventing tidal erosion of the coastal soils.

2. The littoral forests

These include tall evergreen trees and occur on alluvial, high level soils along the sea-coasts but beyond their reach of the sea. They occupy strips of flat coastal land of varying depth, formed by the detritus brought down by streams, and by sands banked up by wind and wave. This type is seen at its best in Rutland Island. The most striking species of this type is Mimusops littoralis. Other species include Thespesia populnea, Pongamia glabra, Terminalia catappa, Calophyllum inophyllum, Barringtonia sp. and Tetrameles nudiflora.

3. The deciduous forests

These are usually leaf-shedding in character and occur on low level undulating ground where the soil is somewhat poor or physiologically less moist than in the evergreen areas. These are amongst the most valuable forests of the Islands. The most noteworthy species is Pterocarpus dalbergioides, which, with its large butterssses, stout branches and spreading crowns, reaches to canopy height of 45 metres. Other equally big tree species include Terminalia procera, Terminalis bialata, T. mannii, Lagerstromis Hypoleuca, Canarium euphyllum, Sagarea elliptica and Diospyros phyrrocarna, various small trees, shrubs and climbers are to be found under this top canopy.

4. The evergreen forest

It is the grandest forest type of these islands. This type clothes the slopes and fertile valleys. The soils that this type favours are well drained valley alluvium and moist fertile loams and micaceous clays in the high hills. The underlying rocks consists, usually of extensive intrusions (serpentine series) in sedimentaries (sand stones). These evergreen forests are equally valuable, as a source of timber and industrial wood of the deciduous type. While the highly prized Padauk is rarely found here, the principal tree species here are the Depterocarps, which grow to large dimensions and reach great heights. The main species found in this type are _Dipterocarous_ spp., _Sterculia companulata_, _Terminalis procera_, _Terminalis bialata_, _Planchonia andamanics_, _Artocarpus_ sp., and _Tetrameles nudiflora_. In the high level areas _Dipterocarpus griffithii_ and _D. turbinatus_ take the place of _D. incanus_. Also found are _Wallichii_, _Endospermum malaccense_, _Hopea odorata_ and _Sideroxion_ longipetiolatum.

5. High hill forests

They are limited and scattered and are seen most in the higher elevations of the middle Andaman, Saddle Peak in North Andaman and Mound Ford in Rutland Island. A stunted, but well-stocked, variation of the evergreen type, it occupies the crests and dry slopes high up in the hills. The principal species here are _Dipterocarpus costatus_, _Terminalia mannii_ etc.

Some of the agrostological species of the Islands are _Paspalum scrobiculatum_, _Paspalum conjugatum_, _Paspalidium germinatum_, _Cynodon dactylon_, _Chloris barbata_, _Echinochloa colouum_, _Echinochola cresgalli_, _Arundo donax_, _Eleusine indica_, _Ischaemum indicum_, _Ischaemum rugosum_, _Brachiaria ramoza_, _Brachiaria mutica_ etc. (Bhattee _et al_., 1963).

Population

The population of these islands as recorded in 1971 was

115, 090. Area, population and density pertaining to the island are furnished in Annexure III. The population of these areas consists of four distinct groups : (1) Andaman tribals, (2) Andaman Indians, (3) New settlers and (4) Nicobaris. The aboriginals or tribals of the Andaman are descendents of a Negroid race. Of them, the forest dwellers-Jarawas and Sentinelese are hostile and are yet to be actively contacted by the Administration. Their number is small but not exactly known. The Jarawas inhabit and move about in some 500 sq. kms. (200 sq. miles) of forests in the western parts of the South Andaman Islands and this area has been reserved by the Administration exclusively for their living. The Sentinelese inhabit the isolated Sentinel Island and are also left alone. Of the two coastal tribes, the Andamanese have become practically extinct; about 20 individuals survive now and are suitably looked after by the Administration. The Onges of the Little Andaman number about 150 and are being gradually induced to adopt improved ways of life. The Nicobarese belong to a race group completely different from the aboriginals of the Andamans. They number approximately 14,000 and the bulk of them live in Car Nicobar and to a less extent in Nancowrie, Katchal and Chowra Islands. The two large Islands of this group, the Little and the Great Nicobars, are inhabited by a few Shompins, a primitive forest tribe. The Nicobarese population has nearly doubled in the last 50 years. They live in fairly well organised communities.

Others are mostly settlers from the main land of India at different time.

Agriculture and Irrigation

The islands indigenous population comprises tribals who are mostly food collecters and not food producers. Jhum cultivation which is prevalent in other parts of the country is not practiced by the tribals of these islands. Hence the island is under the thick green mantle of forest vegetation. Land utilization statistics is furnished in Annexure II.

Permanent agriculture enters the island since the settlement of families from mainland of India. Virgin forests vegetation was cleared and families were settled. The pattern of allotment of land for the settlers is 5 acres of level valley land for rice cultivation and 5 acres of adjacent hilly land for homestead and horticultural/plantation crops. Valley land is being cultivated to paddy during Kharif season and some portion of the land is used for growing oil seeds, pulses, sugarcane, vegetables, spices, etc. in small scale. Homestead land which has been allotted at the lower slopes of hills adjacent to the paddy fields are under cultivation of fruit crops viz., Mango, Citrus species, Jack, Coconut, Arecanut, etc. as main crop and ginger, turmeric, Yams, vegetables, pine apple, etc. as iter crops. All crops are grown under rainfed condition and sometimes suffers from water stress due to ill distribution of the rainfall.

The indiscriminate clearing of forest vegetation for agriculture takes us to the serious problem of soil erosion. Most of the settlers of the islands were from East Bengal and they were not used to cultivation of such hilly lands under rainfed condition and had very little knowledge of soil erosion and soil conservation measures. Cultivation of land having steep or rolling topography without any soil conservation measures had already taken a heavy toll of fertile top soil and the crop yield is dwindling year after year. Some lands had already gone out of cultivation due to soil erosion in its varying forms and dimensions starting from rill to gully erosion. Soil erosion survey conducted in Andaman Islands revealsthe magnitude of the problem (Thampi, 1960).

Consequent upon the findings a land use pattern was suggested by the soil conservation organisation of the island (Thampi 1961). Detailed study of the soils of the Islands are needed for developing better land management system.

Laterisation has not been noticed yet in any part of the Island indicating that the soils of the Islands are still young.

By augmenting the development programmes particularly agriculture for attaining self sufficiency, development of a scientific land management system is an imperative necessity for ensuring the productivity of land on sustained yield. Development of land use plan on catchment basis is an urgent need. This study was initiated to obtain information pertaining to the occurrence of associated soils which are being used for exploitation of Agriculture. This is of paramount importance since agriculture is the main occupation of the population of the island, and their economic stability and prosperity depends on the success of agriculture.

Investigation on these soils was, therefore, taken up with the following objectives :

1. To study the morphological, physical, chemical and minerological characteristics of these soils in relation to catenary association in toposequence keeping in view of the land utilization aspect for agricultural development.

2. Based on the information obtained in the objective 1 an attempt shall be made to throw some light on the genetic make up and classification of the soils under investigation.

3. To relate the study of the soils in the toposequence to the agricultural practices in the islands on catchmentbasis.

4. To facilitate soil survey and interpretation for preparing soil map and land use plan.

REVIEW OF LITERATURE

Soils are formed by a succession of two important processes, first, weathering of rocks and minerals by disintegration and decomposition to form the raw material; second, the conversion of this raw material into soil through the influence of climate, bioshare, parent material and time.

Different types of soils with varying characteristics are formed within a very small area under certain conditions. The diversity of soil characteristics is so marked in some places that soils of red and black colour occur side by side. The existence of diverse soil types occurring in close proximity has been found all over the World and is more common in tropics and sub-tropics than in the temperate region. Such soil associations have been frequently reported in the U.S.A. (Tedrow et al., 1958; Brown and Trorp, 1942; Uehara and Shernan, 1956), Australia (Stace, 1956; Hallsworth et al.,1952; Bryan and Teakle, 1949; Costin 1955), North East Scotland (Glenworth and Dion, 1949), Africa (Milne, 1935; Morison 1949; Calton, 1954; Nye, 1954; Radwanski and Olliver, 1959); Moss, (1965); Watson, (1965); Young (1968); Trincart (1972); Kwaad et al. (1977) and in India as well, viz., in Hyderabad (Desai, 1942); Madhya Pradesh (Sen, 1939; 1939; Bal, 1943), Coimbatore (Raychaudhury et al., 1943), Uttar Pradesh (Mukherjee & Agarwal 1943, Agarwal et al., 1957), Orissa (Sinha & Mukherjee, 1959).

The diversity of soils in most cases is observed in sloping topography than on level plains. The occurrence of soils in toposequence present red soil on the top of the ridge and black in valleys through transitional soils. These show distinct differences in the physical, chemical and morphological characteristics. Though these soils appear to be different in their characteristics they are systematic and regular in their repetitive distribution in the crest and in the landscape. This led Milne (1935) to introduce the concept of catena in defining such group of soils. Morrison (1949) referred to the topographical catena concept as the fundamental concept around which to build the future attempts to classify tropical soils. Duvigneaud as quoted by Trincart (1972) observed catena on the hills of Bas Congo in Africa with distinct vegetative types and soils characteristics.

Concept of Catena

Milne (1935) suggested 'catena' to designate a soil association underlain by parent rock of uniform character. The various soils included in a catena correspond to the links in a hanging chain. To put in his own words, "the catena is the sequence of series and types which though fundamentally different in genesis and morphology, often repeat itself due to similar conditions of micro-relief and differential soil movement and drainage".

In the catenary sequence there is a tendency to mechanical fractionation and translocation of weathering products down the slope by the action of rainfall. In older soils, the catena is largely affected by further differentiation of the fractionation products under their influence of their topographic sites, so that they can be regarded as related indirectly to the primary material. These soils are also affected by the influx of soluble and suspended materials, specially bases, from higher up the slope. Nevertheless, the whole sequence has a unity.

In a catenary sequence, Morison (1949) made a distinction in elluvial, colluvial and illuvial complexes of catenary sequence. He considers, that the elluvial complex, occupying the high level site, is the parent complex which the depletion of water soluble and suspended material will provide a material from which the soils of the other complexes are built up. The colluvial complex occupies slope sites and receives material from the elluvial soils and loses some of it to the illuvial. The illuvial complex, occupying low level sites, distinguishes primarily by the fact that the illuvial receives water under the influence of their topographic position. The catena was described by Calton (1954) as the spread of soil decomposition products across a topographic sequence and their temporary hold-up there as a dynamic phase of soil development. The sequence of soils, being topographically determined, is developed with gradual change down the slope, the transported material from the top acting as parent material on which soil formation takes place.

According to the views expressed above, the catena concept has applicability limited only to the case of the soil gradation in relation to topography, the parent material remaining the same. Bhushnel (1942) was the first to widen the scope of term 'catena' according to whom no locality has soils which may not be repeated as members of a catena and catena cannot exist unless the definition permits certain amount of range in parent material and vegetation. In fact, he suggested the following grouping of catenas in relation to soil forming factors.

1. Chrono catena in relation to time.
2. Byndel-catena in relation to time parent material.
3. Flor-catena in relation to time vegetation.
4. Climo-catena in relation to time climate.
5. Hydro-catena in relation to time moisture component of climate.
6. Thermo-catena in relation to time temperature component of climate.

Thorn (1942) has subdivided catena into two groups - the macro catena and the micro-catena. The micro-catena refers to a group of soils, significantly differing in drainage on some kind of parent rock, while macro catena refers to a broader concept for the soils with more broadly defined points of similarity. Jenny (1941) has made a precise analysis and exposition of broad view of soil classification which puts catenas in their logical place. He states that "the soil is an example of properties which are function of pedological factors". He recognised catena in relation to topography and suggested that toposequence may be sub-divided into climo-hydro- and other sequences. Winter (1949) and Bunting (1935) suggest, by way of explaining the occurrence of diverse soil types, that the catena concept described by earlier workers appears to be of equal importance. Virgo, et al. (1978) described distinct catenas as related to difference in parent material are characteristic of each land form unit but topographic position is a principal factor determining soil distribution within each catena.

The brief discussion above make a better understanding of the "catena concept" which is closely associated with mapping and classification. According to Milne (1936) it is a cartographic unit consisting of soils which, while they fall wide apart in natural system of classification on account of their fundamental genetic and morphological differences, are yet linked in their occurrence by conditions of topography and the same relationship to each other, whenever the same conditions are met with. In explainining any 'catena', the genetic term can be made specific by prefixing a locality name. Thus Uganda foot hill complex is called 'Uganda catena' (Milne, 1935) and the catena in Miami, is called 'Miami catena'.

Geographical distribution of catenary soils

The occurrence of catenary soils in toposequence is reported in many parts of the world.

Ukriguru catena described by Milne (1947) in East Africa; Usulama Catena in Tanganyika, by Calton (1954); Naye (1954) made a detailed study of the formation of typical catena developed over biotite gneiss in humid tropics of West Africa; Cooma Catena of Australia identified by Hallsworth _et al_. (1952). The Peguroma soil catena in Burma described by Edwards, (1940); a typical Caribeu Catena in Canada studied by Whiteeside (1959); Sesaki (1957) studied catena of hydrogenic types in Japan; Miami catena in U.S.A. mentioned by Brown and Throp (1942) are few occurring in different parts of the world. Brief description of some of the catenary soils in India are mentioned below :

Diverse soil types occurring in close proximity have also been observed in many parts in India, viz., Hyderabad (Desai, 1942), Madhya Pradesh (Sen, 1939; Joshi, 1950) in Coimbatore (Raychaudhuri _et al_., 1957) and in Orissa (Sinha and Mukerji, 1959). The variation is manifested more on sloping topography than on level plains. The chain of soils with red on the top of the ridges changing to black in valleys through transitional soils shows distinct differences in characteristics (Mukerji and Agarwal, 1943). Viswanath (1939) made reference to the wide occurrence of such diverse types of soils side by side in many localities in South India.

In Chattisgrah region of Madhya Pradesh, four soil types occurring in toposequence, red _Bhata_ being on the top of the slope merging gradually to black _Kanhar_ in valleys through transitional yellow _Matasi_ and _Dorsa_ are found (Sen, 1939) Joshi, 1950; Biswas & Prasad, 1959).

Pedogenic factors influencing the formation of catenary soils

There is some controversy regarding the relative importance of soil forming factors responsible for the development of soil association. But it appears that topography, climate and parent material are the principal factors which are, independently or in combination, responsible for the diversity of the soils. The role played by each of these factors is discussed below :

Topography

Topography refers to the out line of the earth's surface and is synonymous with relief. It is believed that ultimately all mountaneous areas will be washed down to flat or undulating surfaces but this process is very slow. One of the rapid processes through volcanos played in the past a vital role in these Islands to give the present form. Topographic features fall into three main categories, those produced by tectonic processes, those formed by erosion and those formed by deposition. Initially all major relief features are produced by tectonic processes whether they are uplift, subsidence, differential lateral movement, or vulcanism; subsequently, the surfaces are acted upon by water, ice, wind, frost and mass movement which are the principal agencies of erosion and deposition. Run off water is the main agency of erosion and deposition but the exact processes and stages through which the landscape must pass are not well established. This is a subject of controversy, however, there are two principal schools of thought; those of Davis (1954) and Penck (1953), former regards the land surface as going through series of stages during which the surface gradually becomes subdued and eventually formed a peneplain. In contrast to this, Penck suggests that after the initial incision and down cutting by running water, there is parallel retreat of the slopes to form pediments and pediplains. Virgo et al., (1978) believes difference in topographic position results in similar pedogenetic sequences from older soils on the relatively stable uplands through unstable hill sides, Younger soils on the colluvium mantled pediments and interfluve plains to deep alluvial soils in the topographic depressions. In each instance, accelerated erosion has caused truncation of soil profiles and transport of material down slope to the valley centres.

Studies made so far, in case of certain catenary soils, show that the formation of such catenary soils in affected by varied topography and consequently by the drainage conditions, the other soil forming factors being similar.

In the earlier part of the nineteenth century, Medlicott and Blanford (1933) reported black soils to occupy the flat grounds with red soils on the elevated places in certain parts of India. Basu and Sirur (1938) attributed the formation of black and associated soils on basalts to the drainage conditions resulting from topographical variation. Desai (1942) corroborated the same view on the formation of red and black soils in close proximity in Hyderabad (Deccan).

Sen (1939) also attributed the effect of topography to the formation of these four associated soils in Chattisgrah region of Madhya Pradesh and expressed the view that "red Bhata on the top, which is subjected to constant erosion, is likely to be transported in the valleys and converted into black soil in situ". In a recent work on Vindhyan soils in Varanasi district, Agarwal et al. (1957) further corroborated the influence of topography on the formation of diverse soils. Similar was also the view of Raychaudhuri et al. (1943) in the case of black and red soils of Coimbatore.

Morison (1935) explained the nature and formation of black and red soils in South Western Sudan mainly on the basis of topography. The elevated places with well drained sites were occupied by red soils whereas the soils were black in the low lying areas in the foot of the slope.

Similar views were also expressed by Morison et al. (1948) and Mohar and Van Baren (1959) in Indonesia. According to these investigators the topography which is responsible for the translocation of silica and bases by lateral transport and their accumulation in the valleys was the main cause for the development of red soils at the elevated places and black soils in the valleys. Importance of topography on the formation of diverse soils was further stressed by Sherman and Uehara (1956) who observed that differential leaching which is more related to topography was the main cause for formation of diverse soil types in Hawaii Islands, other factors being constant. Similar are also the observations of Cline (1955) in the formation of soil complexes in Hawaii Islands.

Striking example of influence of topography in the temperate region is clearly evidenced by the work of Tedrow et al. (1958). They showed that the formation of a number of genetic soils in Northern Alaska was mainly due to the drainage conditions.

Studies by Virgo, et al. (1977) in Thailand reveal that on any given land surface Catena, the lateral boundaries of each land surface unit are identifiable in the field on the basis of zone of rapid spatial change of diagnostic pedogeomorphic, physical and morphological properties, that are themselves resultant on a rapid change of relative intensities and combinations of pedogeomorphic process intergrades. Each member of the catena is genetically as well as spacially related to its adjoining members.

It is thus evident that the dominant factor responsible for the formation of diverse soils in close proximity is the topography and the drainage conditions from the topography.

Climate

It is well known that many types of soils are met within the tropics where, from a climatic point of view, they are not expected to occur at all. The diverse soil types found in close proximity are good examples of this. Regional intrazonality of this kind layes emphasis on the need for reconsideration as to the validity of climatic factor as a main one in soil formation. In the words of Mohr and Van Baren (1959), "the fact that the present day overhead climate is much more an over estimated factor while the significance of the soil climate has generally been neglected (or at least underrated), may explain why exceptions to climatic conception are more numerous and are of greater importance in tropical region than conformities to zonality".

The present day climate may not explain the diversity in the zonality of the soils. Naturally there has been attempt to explain it on the basis of the past climate or the soil climate. This concept has been utilised by Ellis (1938) in explaining the formation of black soils in Rhodesia. In his opinion, the occurrance of typical chernozem soils with calcium carbonate accumulation in a region of 40 to 50 inches of rainfall may be an evidence of influence of the drier climate of the past rather than the present high rainfall condition.

The same reasoning has been applied by Miege (1931) (as quoted by Joffe, 1949) in explaining the close existance of widely divergent soils i.e. Tirs and Hamri of Morocco. The Tirs are typical black soils whereas Hamri are the red soils which are more weathered than the Tirs. He expressed the view that red soils were formed under previous cycle of weathering under climatic condition different from that of the present and considered the

Hamri as a formation in the cycle of weathering proceeding the the Tirs.

The influence of past climate was also assumed by Pendleton (1947) in explaining the formation of laterites and black soils in close association in Mendsaur district of Madhya Pradesh. He expressed that laterites could never be formed under present semi-arid climate and like Miege (1931), he assumed that the laterites developed when the climate was humid and different from the present one. He considered formation of laterites to have taken place in the tertiary period before the Western Ghat cut off a great deal of monsoon rain, making the climate semi-arid from the period onwards.

This sort of assumption has been further elaborated by Hallsworth (1951) in explaining the occurrance of red soils with other types in the Lismore district (Australia). He considered the red soils were the relics of a previous wetter climate, probably of the hot wet period of middle tertiary, whereas black soils were developed from the later out croppings of basalt under the present climate.

For a clearer exposition of this phenomenon, Bryan and Teakle (1949) advocated the concept of 'Pedogenic Inertia' which implies that a soil formation process once established continues in spite of subsequent changes in the environmental conditions. To be more precise, this means that soils formed quite a long time back under different climate are persist in retaining their acquired characteristics even when it is in equilibrium with the subsequent change in the climate set up for a very long period. This assumption has support from their work as quoted below.

It was proposed by Bryan and Teakle (1949) that there had been several stages in pedogenic environment since the basalt flows ceased. According to their postulation, under very nearby environment red soils with lateritic characteristics were formed. Later, red soils without lateritic characteristics were formed where basalt was exposed, and still later black soils formed where basalt was exposed. They also assume that these different types persist in retaining their acquired characters during the climatic era and do not change their characters under present day environment. They have further explained that the red soils are pedalferric with kaolinitic type of clay whereas black soils are pedocals containing montmorillonite-beidellite group. The hypothesis put forward by them is that as a result of wetter climate, the red soils were initially developed and as a result of 'pedogenic inertia', they have persisted in spite of lower rainfall under black soils were formed.

Basu and Sirur (1958) had probably the same idea of wheat Bryan and Teakle (1949) called as 'pedogenic inertia', in explaining the existance of diverse soils in Deccan plateau. In their own words, "Although the soil building forces are still at work, due to the dynamic nature of the relief, yet these soils must have reached a state of equilibrium with climate, natural vegetation and long standing agricultural practices".

Climate is the principal factor governing the rate and type of soil formation as well as being the main agent determining the distribution of vegetation and the type of geomorphological process, therefore, it forms the basis of many classification of natural phenomena including soils. A number of workers have introduced climatic indices based on atmospheric climatic data. These are of little value, since atmospheric climatic data often have little pedological significance. Transeau (1905) shows the amount of percolation, relative to evaporation so that on the value increased above unity, the amount of moisture available for percolation through the soil increases. This may be true for easily permeable soils on flat sites, with complete through drainage but it is of little value for soils with compact impermeable layers on those at the lower end of the slopes and in depressions that receive a considerably larger volume of moisture by run off.

Although a number of scientists refer to the influence of climate on the formation of diverse soils, the micro-climate plays no less important role. The importance of micro-climate has been clearly pointed by Jenny (1941). Small areas are characterised by a distinct micro-climate that may differ considerably from the macro-climate. Official rainfall and temperature records deal with the macro-climate. Lower temperatures in depressions, high air humidity along the creeks, and modification in the environment due to different types of vegetational cover may be taken as example of the micro-climate.

Penmann (1942) refer to a very similar example of the influence of micro-climate in Switzerland on the formation of humus carbonate soil in one case and degraded acid humus carbonate soil on the other hand. This concept was to some extent applied by Lotspeich and Smith (1953) in studying the Palouse catena. They expressed the view that variation in micro-climate, due to the exposure and localized accumulation of snow, was dominant in determining the soil differences. According to them, the zonal prairie soil and palouse silt loam are found only on the relatively gentle south facing slope. A profile with chernozem morphology, the Athena silt loam, is on the dry ridges.

This aspect of the influence of micro-climate has been well explained by Costin et al. (1952). They reported the most interesting topographically controlled micro-climatic sequence occurring on gneissic granite on the lower sub-alpine and upper montane tracts of the New South Wales, where the broad valley is strongly affected by cold air drainage. Under these conditions, the coldest parts of the catena are on the top and bottom of the slope and the warmest part on the middle. Thus, the sequence consists of alpine humus soil on the top of the slope, transitional alpine humus soil in the cooler upper part, brown podsolic soils on the warmest middle slope and the transitional alpine humus soil on the cold valley floor.

The influence of micro-climate is thus evident on the formation of catenary soils.

Parent Material

Jenny (1941) defines parent material as the 'initial state of the soil system'. The precision of this definition cannot be questioned but most attempts to determine theinitial stages of soils are met with difficulties, for in a number of cases the original character of the material has been so thoroughly changed by a long period of pedogenesis that it is only possible to speculate about the full composition of its prestine state.

The references quoted previously stress the importance of topography as the predominant factor in the formation of such associated soils. But the parent material according to some is not absolutely passive. Particular mention may be made of the work of Ramiah and Raghavendrachar (1936) who were strongly of the opinion that occurrance of red and black soils side by side in Madras State was due to the variation in chemical composition of the parent material. The black soils are developed from the rock containing mainly soda lime feldspar whereas red soils are derived from rocks containing potassium feldspar. But the composition of the parent material which has undergone much chemical changes through the action of weathering is a matter of secondary importance.

The importance of the characteristics of parent material on formation of diverse soil types has got further support from the work of Vine (1949) who observed that catenary soils in Nigeria were mainly determined by the geological formation, the nature of the parent material and the history of weathering. The same discrepancy is observed in Jamaica where, in the same belt of low rainfall (1000 mm per annum), reddish-brown and black soils occur close to each other in the same flat land region. Both the soils are derived from calcareous rocks (Hardy and Croucher, 1933).

Virgo, et al.(1977) who studied the mountaneous terrain in South Thailand observed parent materials that weather rapidly or that were deeply weathered in an earlier phase with the production of high Swelling clay minerals that readily disperse on wetting, intermittent tectonic uplift and volcanic activity in the recent past resulted in much deeply dissected relief and little low lying land. In Rhodesia, formation of associated soils in widely different climatic conditions was mainly influenced by parent material (Staples & Murray, 1951). It is equally interesting to note here that although the parent rock may be the same in such soils, there is likelihood of change in the composition of the parent material. This is to some extent emphasised in the work of Muir et al.(1957) on the catenary soils of Tanganyika. In this case, parent rock was mainly amphibolite, but varied sufficiently to be reflected in the appearance of some of the shallower soils.

Whiteside (1953) and Brewar (1964) have suggested methods for classifying parent materials. In the system of Whiteside a somewhat general statement is made about the minerology and state of the material while that of Brewer is really an attempt to classify the potential of the material rather than a statement about the material itself.

The few references quoted here indicate that the parent material may be partly responsible for the diversity of soils. This probably led Milne (1936) to widen the scope of the 'Concept of catena'. According to him, 'catenary association' may be of two different classes; in one, the parent material is similar, the topography being modelled out of a single type of rock at both higher and lower levels and in the other the topography has been curved out of two superimposed formations. The same author (1947) reported the characteristic influence of parent material on the pedogenic significance of hard pan soils of Tanganyika.

Morphological, Physical and Chemical characteristics of Catenary Soils

Morphology

The first morphological characteristics which manifest itself prominently in the diversity is the soil colour. The change is from red or reddish at the top to dark gray in the valley through several transitional stages. The soil sequences, whether it consists of two or more members, always shows that the upper members are shallow, stony and light textured. The depth of the solum increases down the slope accompanied by change in texture from light to heavy. The other important characteristics which show gradational variations down the slope are change in structure from single grain to sub-angular blocky, increase in consistency and absence to presence of lime concretion down the slope. Each of the members of a catena is a soil series by itself, having characteristic features connoting the influence of soil forming processes. The profiles as a unit are distinct from one another.

Physical and Chemical properties

Black soils in the valley are distinctly more clayey than the red soils in the upper portion of the slope. Black soil in the depression presents considerable uniformity in clay throughout the profile while red and other soils show increase down the profile. Water holding capacity and volume expansion are generally higher in black soils as compared to red soils.

Red soils are generally free of calcium carbonate which is characteristically profuse in the black soils in the form of concretions (Desai, 1942; Raychaudhuri et al. 1943; Hallsworth et al. 1952; Agarwal et al., 1957). Contents of organic carbon are somewhat higher in black soils as compared to the red soils although there is appreciable variation in nitrogen. Desai (1942) observed higher C/N ratios for black soils whereas Joshi (1950) and Agarwal et al. (1957) observed similar values for red and black soils.

Pawluk *et al*. (1978) observed that the soils developed from acidic parent material derived from shales of Cretaceous age has low pH and base saturation values and encourages the formation of hydrated iron oxides. The ion oxides impart to the B horizon reddish hues of high chroma.

Cation exchange capacity of the soils are found to increase down the slope. Hallsworth *et al*. (1952) observed dominance of trivalent cations in the exchange complex of red soils. The clay fractions of the red soils are usually lower in silica-sequioxide ratios as compared to black soils which are also richer in bases.

Results so far recorded on free oxides of iron and aluminium of such soils are contradictory. Raychaudhuri *et al*. (1943) found black soil to be higher in free alumina and red soil in free iron oxide whereas Desai (1942) found both these constituents to be higher in red soils. Nye (1955) and Agarwal *et al*. (1957) observed higher contents of free iron oxide in the clays of red soils than in the black soils. Similar was observation in the clay fractions of catenary soils of Raipur (Prasad and Biswas,1959). Free alumina did not differ in the two clay fraction of the soils.

Factors responsible for colour of catenary soils

Reference has been made to the wide variation in the colour of a soil sequence. There are all hues and shades of grey, yellow, red and brown soils between the two extremities. Various theories have been advanced and various factors attributed to for the colour of the soils and also for the interesting gradation in colour. The different factors which have been thought to be responsible for the colour gradation are titaniferrous magnetite, organic matter, nature and quantity of clay, moisture, calcium and iron status of the soils. This is discussed below.

Black soils

The colour of black soils in the tropics is a matter of interest and received attention in earlier part of this century. Annet (1910) probably was the first who tried to correlate the black colour with titaniferrous magnetite content of the soils but this theory was untenable as a number of soils other than black contain more titanium (Harrison & Sivan, 1912). It was indicated that the black colour may be due to the interaction of some effect of the organic matter with silicate complex. Next possible explanation of the black colour formation was naturally attributed to the organic matter. In a temperate climate, organic matter imparts dark colour to the soil, but this does not hold good in case of tropical climate where the black soil is poorest in organic matter. This point was made very clear by Basu and Sirur (1938) in their studies on black soils of Bombay Deccan and also by Del Villar (1944) in his studies of black soils (tirs) of Morocco. He did not find any correlation between the dark colour of the black soil and humus content. He, however, indicated the importance regarding moisture status of the soils.

A number of earlier workers (Denial & Langham, 1938;

Scheffer, 1943) tried to correlate the black colour of the soils with the high organic matter content. According to them, it is not the amount but the nature of organic matter which is responsible for colour of the black soils. Brammer and Endredy (1954), while studying the black and associated soils, found that the colour of the black clays was primarily due to organic matter. They also noted that removal of manganese had a little effect on the colour.

Taking overall account of these observations, it is evident that organic matter along with topographic situation which ultimately results in variable moisture status of the soils is the influencing factor.

Similarly, Robinson (1949) stressed the influence to topographic changes rather than the chemical composition of the rock on the formation of red and black colour of the soils. He points out that in the valley with restricted drainage the calcium ions in the sphere of weathering prevent the loss of silicic acid, and thus resulting in dark coloured soils with siliceous clay complex. The red soils, however, develop with low silica-sequioxide ratio under the condition of free drainage and low lime status. He is of the opinion that dark colour is due to the humification of organic matter under base saturated conditions of the soil in neutral or even in alkaline medium and not to the higher organic matter content as certain red soils also have a higher organic matter content than the black soils. This is to some extent similar to the view of Marshall (1935) according to whom black colour developed is due to the humic matter existing as a calcium salt of the organic colloidal acids.

Further supporting evidence for such mechanism of formation of black colour comes from the work of Desai (1942) who holds the view that the following two factors may be responsible for the dark colour :

1. Humus in fully saturated conditions have been shown by many workers to be very dark in colour.
2. Since the soils are wet, the iorn, which is largely in finer fraction is in a reduced condition and thus adds to the dark colour of the humus.

The other factor in the colour formation is the amount and nature of clay. However, it had a negative significance from the work of Raychaudhuri et al. (1943) and Agarwal and Mukerji (1946), according to whom chemical composition has no bearing on the colour of soils. But Joshi (1950), on some soils of Madhya Pradesh presented evidence to show that clay or rather clay humus complex is the contributing factor. He noticed that black soil contains much more percentage of clay than the red ones and expressed that it is the intrinsic property of the clay which fixes humus in a certain proportion to form clay-humus complex which imparts black colour to the soil.

This shows that not only the organic matter and clay but the clay-humus complex also in combination with base saturation with particular reference to calcium plays role in this mechanism of colour formation. Ashgar et al. (1949) obtained a good correlation between the exchangeable calcium and colour of black soils.

Intimate relationship or calcium status of the soils with their black colour has been nicely shown by Singh (1954). It was very difficult to remove the black colour by simple treatment with hydrogen peroxide, particularly in black soils which are invariably calcareous. Singh (1954) showed that this organic matter could be oxidised only when carbonate was removed with hydrochlorid acid, otherwise decolouration of black soil was not possible. This clearly shows that black colour is associated with organic matter and calcium status of the soil.

In a further study on the reaction different clays with anaerobically fermented grass extract, Singh (1956) observed that high cation exchange capacity of montmorillonite type clay favoured the formation of dark clay-organic complex in intimate association with organic matter. Sodium clay adsorbed comparatively higher amounts of organic matter, giving distinctly darker colour. He further observed that sorption of organic matter and formation of dark colour were invariably associated with sorption of iron, manganese, calcium and magnesium. The formation of dark grey colour was considerably pronounced between pH 7 to 9 and 3 to 5, and this can be very well explained by the work of Jackson et al. (1949).

Recently, Stace (1956) while studying the terrarossa and rendzina soils of South Australia, reported that the colour was largely dependent on the ratio of the free ferric oxide associated with the clay fractions to the total nitrogen content of the soil. He termed the ratio as "colour index". With a few exceptions, the ratios were less than 10 for the rendzinas (black) and greater than 10 for the terra rossas (red).

From the facts mentioned above, it appears that not a single factor but a number of factors are responsible for the colour of the black soils, viz., nature of the organic matter, amount and type of clay, moisture status, exchangeable calcium and calcium carbonate content.

Associated soils

While the factors discussed above account for the colour of black soil on the one extreme, the different forms and contents of iron have been attributed for the colour of red and the intermediate soil types. According to Hardy (1935), the colour is briefly a function of the degree of hydration of iron oxides which in turn depend mainly on rainfall. The colour, he says, is yellow or orange when the hydration is high, red or crimson when the hydration is low. This view of Hardy is supported by the work of Gadre and Gokhale (1939) who attributed difference in colour to iron in various stages of hydration. Similarly, Kelley et al. (1939), in case of soils of California, observed the free oxides and free hydroxides of iron to be the common constituents of all the soils to which they imparted red or yellow colour and believed that red soils owed their colour to the presence of haematite. Further supporting evidence for such mechanism of colour formation was indicated by the work of Karim (1953) who was of the view that the free ferric oxide influenced the red, yellow or brown colour of the soils.

Oxides and hydro-oxides of iron were considered to be the chief colouring constituents of the soils of Madhya Pradesh (Joshi, 1945). After the removal of free oxides and hydroxides of iron, the residue from black soil was still black, whereas yellow and red soils completely lost their colour. He attributed the red or yellow colour principally to these iron compounds. This point was made very clear by Stace (1956). He found that, after removal of free oxides from soil, red soil lost its colour and there was good agreement between the redness of the soil and free iron oxide content in the clay portion of the soils.

A brief summarised account of soil colour has been given by Russel and Russel (1958). They have attributed the red, yellow and brown colour to the hydration ofiron under different climatic conditions. They consider that red colour is probably developed in a climate having a hot annual dry season, whereas the yellow is more common either under a hot uniformly wet climate or under a hot climate in which hot weather coincides with rains and colour weather with dry season. However, soils without ferric oxide have white to pale yellow or brown colour. The difference in colour, they consider, is presumably due to the iron being present as <u>limonite</u> and hydrated FeO (OH) under normal humid conditions but this is converted to haematite under high dry conditions. Whenever drainage is impeded, the yellow brown colour is usually dominant.

The work discussed so far restrict to the iron or free iron. But later, there was attempt to find the exact form or compound of iron which imparts to the soil red or yellow colour. Waegemans and Henry (1954), in their studies of latosols, observed that the yellow soil contained free Fe_2O_3 H_2O and red soils from Fe_2O_3. Soils of the intermediate colour were expected to contain mixture of Fe_2O_3 H_2O and Fe_2O_3 but since the hydrogen index of free iron, oxides was the same for different samples of the same colour, they concluded that the colour of latosol was not related to their iron oxide content except in the extreme cases of red and yellow soils.

These observations can be further corroborated by the work of Uehara and Sherman (1956). They are of the view that goethite and haematite are probably the main colour constituents of the red soils. Similarly, Raymond (1942) who made X-ray analysis of black and red sediments found the haematite as main constituent in red sediments.

Mineralogy of the Catenary Soils

Clay minerals

A general appraisal of the few papers shows a general trend that the kaolinitic type of clay mineral is predominent in well-drained soils (upland soils) of the catenary series whereas montmorillonite type of mineral is predominant in the lower members of the group which are formed under impeded drainage conditions.

As early as 1940, Nagelschmidt et al. (1940) found that montmorillonite was predominant in black soil clays whereas kaolinite and halloysite were the main constituents of red soil clays of Hyderabad. Raychaudhuri et al. (1943) confirmed this observation in the case of contiguous black and red soils of Coimbatore.

The influence of drainage on the formation of clay minerals from the same parent material of basaltic soils in Australia was pointed out by Hosking (1940) who found kaolinite under good drainage and montmorillonite under impeded drainage conditions.

These observations can be further corroborated by the study of Edelman (1946). He established the fact, beyond all doubts, that kaolinite is formed under acid conditions and is characteristic mineral of the laterite soils while montmorillonite is the typical component of the clay fraction of neutral to slightly alkaline black soils.

The work so far discussed refer mainly to two extreme diverse soils types, namely, red and black soils. Subsequent investigators became interested in the clay mineralogy of the transitional soils also. In this respect, the work of Hallsworth et al. (1952) and Muir et al. (1957) deserve particular mention.

Hallsworth et al. (1952) studied the clay mineralogy of catenary soils in Australia. The clays of the chernozem derived mainly from basaltic parent material are mainly composed of montmorillonite with smaller amounts of kaolinite and occassionally traces of quartz and illite, kaolinite predominating in the reddish chocolate soil. Normal chocolate soil shows distinct decrease in montmorillonite with corresponding rise in illite and kaolinite. Thus, at lower level, the condition of high base saturation produces a clay predominantly of montmorillonite beidellite group, but absence of such pronounced saturation by virtue of their topographic situation results in the rapid break down of montmorillonite and consequent formation of illite and kaolinite minerals.

Further supporting evidence was given by the work of Ferguson (1954) in the mineralogical composition of black, red and transitional soil types developed from basalt. They observed that the montmorillonite is first formed. The further transition to red soils in certain situation is due to the partial decomposition of montmorillonite to minerals of kaolinite group by loss of alkalies and iron, the latter being established in the upper horizon as hydrated oxides. Further decomposition of kaolin mineral produces gibbsite.

Gupta and Raychaudhuri (1973) who studied clay minerals in different groups of soils of India, observed that in soils clay minerals are not stationary but are always in dynamic position due to a large number of environmental factors, such as parent rocks, climate, topography, vegetation etc. Illite and chlorite were the dominant clay minerals with small amounts of sepiolite and montmorillonite in the desert soils of Ferozpur, Gurgaon and Nilokheri (Kanwar, 1959, Mitra, 1959). This was inconsistant with those of Millot, (1953), and Grim (1954), according to whom the sepilite was the dominant clay fraction in desert soils.Illite with a fair amount of attapulgite were the chief clay minerals in the desert soils of western Rajasthan, except one (highest rainfall region) which contained montmorillonite. Dhawan and Kahlon (1962) observed that the montmorillonite type of clay mineral was characteristic of an early mica of an intermediate and Kaolinite of an advanced stage of weathering. Ferromagnesium minerals (augite, hornblende and phyroxenes) had been reported to produce montmorillonite type of clays whereas felspar formed Kaolinite. On the other hand, granites and Pegmatities produced Kaolinite; and mica, slate and shales formed illite type of clay minerals (Mukherji, 1958; Tamhane et al., 1959) found calcareous type parent material, such as limestone,, was favourable for the development of montmorillonite but blocked the formation of Kaolinite, whereas potash rich parent material was responsible for the formation of illite.

Marshall (1935) observed montmorillonite, beidellite and some of the nontronites are members of a single series. In montmorillonites the chief lattice replacement is of magnesium for aluminium; in the beidellites that of aluminium for silicon predominates; in many nontronites each of these is over shadowed by the substitution of iron for aluminm. The factors favouring the formation of montmorillonite are not fully evaluated.

Nye (1955) in studying the catenary soils in West Africa found that clay minerals formed under restricted drainage were of montmorillonite type, whereas under free draining soils these were predominantly kaolin with subsidiary quartz, goethite and trioctahedral mica.

In a catenary sequence in Tanganyika studied by Muir et al. (1957) each of the soil types is characterised by the particular type of clay minerals present. The red soils have fine grained kaolinite as the dominant clay mineral, often associated with haematite and occassionally minor amounts of goethite and illite, whereas pallid and grey soils contain illite in addition to kaolin, haematite and little quartz. The dark grey Kongwa soil showed illite with a little kaolin and black soil showed montmorillonite with 20 to 30 per cent kaolin.

McAleese and Mitchel (1958) found that the change in minerological composition of the profiles was closely related to the drainage conditions. The dominance of kaolin appears to be the end product of weathering where weathering and base depletion were most pronounced. Vermiculite predominated under good drainage conditions and was gradually replaced by montmorillonite as the drainage become poor.

The above observation is in confirmity with the weathering sequence of Jackson et al. (1948) who held the view that a primary mineral is weathering directly to secondary minerals. Montmorillonite in the tropical clays will be converted into laterite soils with kaolinite as a dominating clay mineral. This happens if the black clay is sufficiently leached due to the adequate drainage which favours the breakdown of montmorillonite to illite and kaolinite.

Primary minerals

Mineralogical make up of the fine sand fractions of the catenary soils has been studied only in a few cases. Nagelschmidt et al. (1940) were probably first to report on the primary minerals in such soils. They found red soils of Hyderabad to contain feldspar and hornblends, indicating presence of basic elements in the non-clay complex of the soil, whereas Raychaudhuri et al. (1943) found comparatively less garnet in black soils as compared to the red soils.

Haverdieve et al. (1977)studied characteristics of mineral constituents of some albic and spodic horizons as related to their change in properties observed primary minerals such as quartz, feldspars and to lesser extent hornblende and magnatite were the major constituents of the coarser fractions. Presence of montmorillonite was confirmed by glycerol solvation which led to an expansion of the 14.3 A^o Peak to 18 A^o. Saturation with K followed by heating at 350 and 550^{o}C led to a gradual colapse from 12 A^o at room temp. to sharp 10 A^o following heating at 550^{o}C. Presence of montmorillonite has been frequently reported even though the acidity of this horizon is not necessarily a geochemical environment suitable for montmorillonite formation. In addition to montmorillonite in the colder A_2 horizon significant amount of hydrous mica was also present. As a result of preferential weathering, some of that mica had been altered to form a mixed layer mineral, hydrus mica-montmorillonite giving diffraction lines at 12.1 and 24.2 A^o.

Margaret Nicholson, (1977) during his studies on pedogenesis in subarctic iron - rich environment observed the leaching, sesquiozide translocation and surfacial organic matter accumulation. The soils are acidic and leaching is generally confirmed. Morphological evidence of podzolization occurs in well drained soils, and the translocation of Fe, Al and organic matter in the profile is noticed. In soils that are waterlogged for only a part of the summer, there is morphological and chemical evidence of podzolization and gleying, as shown by translocation of Fe, Al, Mn and organic matter and by mottling.

In their detailed study on the mineralogical association in the black and red soils of South India, Tamhane and Sen (1954) observed that black soil was mostly associated with the basic make up of the non-clay portion. When soil becomes poorer in basic minerals colour is red. Thus they consider that a kind of dynamic balance is maintained between the non-clay complex and clay complex.

The yellow soils contain more of unweathered primary minerals, viz., Feldspar and hornblends than red soils.

Soil classification

Soils are classified according to the differentiating characteristics and the level of differentiation. There is no universally accepted system of soil classification and nomenclature. Differences exist between the various approaches used by different countries. The soil survey staff (1960) U. S. A. brought out a comprehensive system of soil classification known as 'the 7th approximation'. Soil Survey staff, U.S.Department of Agriculture later gave out a comprehensive system known as soil Taxonomy (1968). The first International Scheme originated when the Commission for Technical Co-operation in Africa (CCTA) produced in 1964 the soil map of Africa 1.5000000. The explanatory monography (D'Hoore, 1968) attempted to combine French (ORSTOM) andBelgian (INEAC) work in Africa. FAO produced an International system (Dudal, 1968, 1974) for the preparation of soil map of the world. The CCTA soil classification system has since been used in African Countries and Land Resource Division of Britain. The classification is natural one and mostly genetic except for the anamalous use of colour to sub divide ferrallitic soils. The division of groups into soil types is frequently on the basis of parent material.

The FAO itself disclaim that their classification system is a universal type. Although many of the soil groups are natural soil types, this is structurally an artificial classification. It makes use of the principle of diagnostic horizons together with most of the horizon names and definitions from the US 7th Approximation.

The French (ORSTOM) classification (Aubert, 1965) is a natural system, based not on single parameters or diagnostic horizons but on the evolution of the profile. In principle it has the interest in natural system. It is not a classification of its own sake, but an embodiment of views about the nature of soil evolution, and has been of particular valuable contribution to understand the development of soils.

The United States 7th Approximation (1960) (with subsequent amendments) is hierarchical with six categories : orders, sub-orders, great groups, sub-groups, families and series. The main feature is the use of diagnostic horizons, defined in lengthy but precise terms. For each parameter there are precise quantitative limits given, together with specification of analytical procedures. The disadvantages of the system, apart from its nomenclature, include the extreme complexity, excessive reliance on laboratory analysis, dependence on parameters of the annual soil moisture and temperature regimes for which data are rarely available. Besides there is likely to have difficulty in field survey owing to the rigidity of the class boundaries, the natural landscape units commonly containing more than one higher category class (Webster, 1968a, 1968b).

The earlier two Australian classification was a generalized descriptive type (Stephens, 1962). The main account is given by

Northcote (1971) and is methodologically of interest in being an artificial system based almost entirely on morphological properties identifi~~e~~able in the field with one exception in its use of reaction. It has a descending hierarchical structure with five categories, sub-division in each category being based on single properties. The division of the highest category is based on the texture of the profile, defined as the variation of texture with depth. The system is artificial and illustrates the advantages and limitations of such as approach. The key is easy to use and profile can be placed into its class from the field survey data.

U.S.S.R. system of soil classification (Basinski, 1959; Ivanova and Rozov, 1960; Tiurin, 1965; Gerasimov, 1968; Rozov and Ivanova, 1968) is on genetic approach with a multivariate structure based on the effect of climate, drainage and parent material.

In the early days in India (2500 B.C. to 600 A.D.) soils were divided into two classes, viz., 'Urvara' (fertile) and 'anurvara' or 'Ushara' (Sterile). Urvara soil was sub-divided into different kinds was respect to crops, e.g. Java (barley), tila (seasmum), Urinbi (rice) etc. Anuvara soil was sub-divided into 'Usara' (salt land) and maru (desert). Apart from the above general classification, local names of soils which confirm fairly to the soil classes were developed. In the beginning of the present century attention was focussed on improving the productivity of the land. Classification of land based on the contents of nutrients, viz., nitrogen, phosphorus andpotassium and also of lime of the top six inches of soil was undertaken in selected areas. In more recent years classification of soils on the basis of studies on the morphological features of soil profiles and physico-chemical and minerological studies of profile samples have been carried out. Emphasis has been laid on the classification of soil at the lowest level from the utilisation point of view (Raychaudhuri, 1964).

Soil classification and soil fertility maps were prepared in the early twentieth century based on the colour. Systems of soil classification based on soil profile and soil genesis on the lines of the USDA system were later developed in India.

Parsons et al. (1976), Fredevic (1976) found soil geomorphology studies have beneficial effect on mapping, classification and interpretation.

MATERIALS AND METHODS

Materials

A brief account of the different soils occurring in close proximity and particularly with reference to their existance in toposequence in different parts of the world has been dealt with for Andaman and Nicobar Islands. Different soils grade gradually from one to the other in a toposequence and this was found to be repetitive in other parts of the region. The sequence comprises soils of (i) Upper slope, (ii) Mid slope and (iii) Valley. This led Sen (1939) to postulate the possibility of changing one soil type to the other. Subsequently, soils of similar nature were studied by Bal (1943) and Joshi (1950) but the study was not in detail. Till very recently Andaman and Nicobar Islands forms a part of oceanic region in the Bay of Bengal were lying unexplored. By augmenting the resettlement of thousands of displaced persons, development programmes in the field of Agriculture and Forestry have gathered momentum. Available knowledge of the soils does not allow full appreciation of the difference between various soils, nor a full comprehension of their potentialities and their problems of amelioration. Three soil sequence from Diglipur in the North Andaman, Rangat in thé Middle Andaman and Great Nicobar in the southern Nicobar group of Islands wereselected for studies. Geology climate, natural vegetation, agriculture and soils are briefly described below :

Location of soils collected

The Andaman and Nicobar Islands lie like an arc between

6° and 14° north Latitude and 92° and 94° of east longitude in the Bay of Bengal, with a 10-degree channel separating the Andaman from Nicobar Group. The Islands lie in a long, narrow, broken chain approximately north-south, suggesting a former land connection from cape Nagrais at the southern tip of Burman to Achin Head (Cape Pedro) in Andalas (Sumatra). The Head quarters Port Blair is 1255 kms from Calcutta and 1191 kms from Madras. The Andaman and Nicobar Islands constitute the most isolated part of India, separated from the main land and from neighbouring countries with vast stretches of sea in every direction (N.C. A.E.R., 1972).

The Andaman group stretches over 464 km. in length and has maximum breadth of 51 km., the average width being only 24 km. The Nicobar group, further south, covers 293 km. between the fartherest points and 57 km. in the maximum breadth. 258 Islands, large and small constitute the Andamans while 61 islands make up the Nicobars. Of these, only a few are larger, viz., the North Andaman, Interview, Middle Andaman, Havelock, South Andaman, Rutland and Little Andaman, in the Andaman group, and Car Nicobar Teressa, Camorta, Nancowrie, Katchal, Little Nicobar and Great Nicobar in the Nicobar group. The others are small, some of them barely a fraction of a square mile in extent. The land area in Andaman group is 6340 sq. km. and in the Nicobar group 1953 sq. km. Soil investigation sites are situated in following islands :

Name of the Islands	Location	Toposequence
North Andaman	Port Cornwallis (North Andaman)	Diglipur sequence
Middle Andaman	Rangat (Middle Andaman)	Rangat sequence
Great Nicobar	Campbel Bay (Great Nicobar)	Nicobar sequence

The above soil investigation sites are shown in Plate II and III.

Soils of the three toposequences cited above are of major occurrance in the islands and is under process of exploitation for Agriculture, Plantation crops and Foresty. Brief description of the soils of each sequence is furnished below :

DIGLIPUR SEQUENCE

Diglipur upper series (D.I.)

Comprises very deep, well drained, Dark reddish brown soils occurring on steep upper slopes of medium hills. The texture of the surface soil is loam and sub-soil is clay loam. The soil is moderately eroded and is under mixed deciduous forest (Mollic Hapludalfs).

Diglipur mid series (D.II)

Comprises, very deep, well drained, dark yellowish brown soils occurring on strongly sloping mid-slope of medium hills. The surface soil texture is sandy clay loam and sub-soil is clay loam. The soil is moderately eroded and is homestead land under horticulture crops (Typic Hapludalfs).

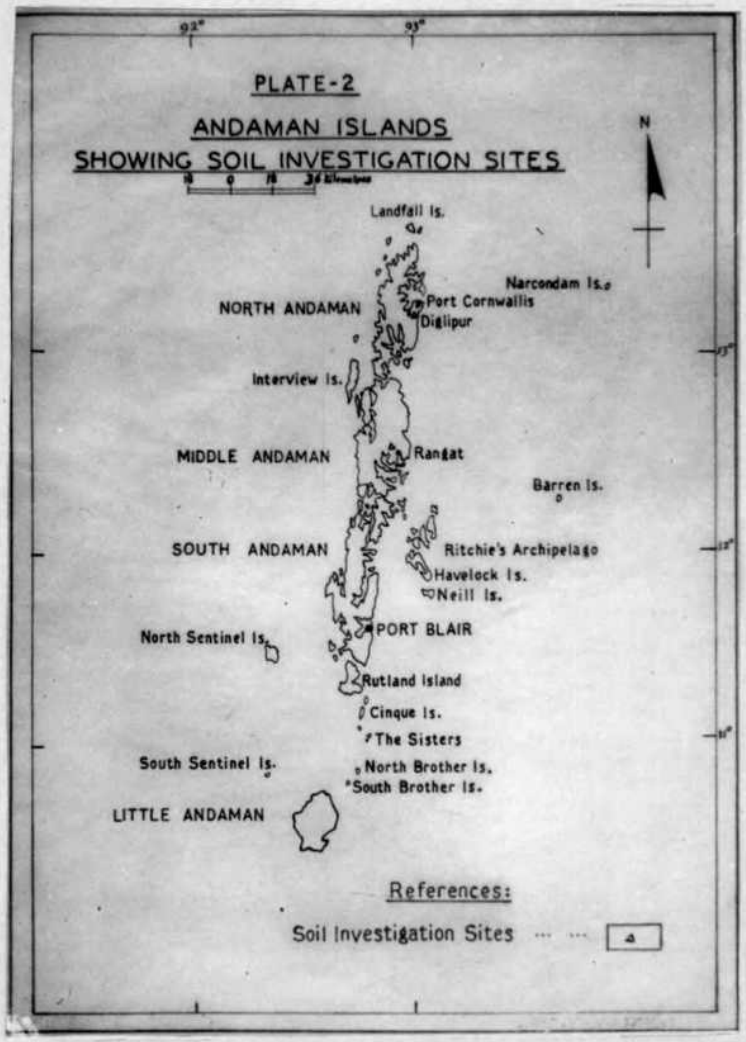


PLATE-2
ANDAMAN ISLANDS
SHOWING SOIL INVESTIGATION SITES
N
Landfall Is.
Narcondam Is.
Port Cornwallis
Diglipur
NORTH ANDAMAN
Interview Is.
MIDDLE ANDAMAN
Rangat
Barren Is.
SOUTH ANDAMAN
Ritchie's Archipelago
Havelock Is.
Neill Is.
PORT BLAIR
North Sentinel Is.
Rutland Island
Cinque Is.
The Sisters
South Sentinel Is.
North Brother Is.
South Brother Is.
LITTLE ANDAMAN
References:
Soil Investigation Sites ... ...

Diglipur Valley series (D.III)

Comprises very deep, imperfectly drained, very dark grayish brown soils occurring on very gently sloping valley land. The surface and sub soil textures are clay loam. The soil slightly eroded and is under crop cultivation (Typic Ochraqualfs).

RANGAT SEQUENCE

Rangat upper series (R.I)

Comprises very deep, well drained dark reddish brown soils occurring on steep upper slopes of medium hills. The texture of the surface soil is loam, and sub soil is clay loam. The soil is slightly eroded and is under mixed deciduous forest (Mollic Hapludalfs).

Rangat mid series (R.II)

Comprises very deep, well drained, yellowish brown soils occurring on strongly sloping medium hills. The surface texture is sandy clay loam and the texture of the sub-soil is clay loam. The soil is moderately eroded and is under horticultural crops (Typic Hapludalfs).

Rangat valley series (R. III)

Comprises very deep, imperfectly drained, dark grayish brown soils occurring on gently sloping valley lands. The texture of the surface soil is clay loam, and sub-soil is clay. The soil is slightly eroded and is dominantly under paddy cultivation (Typic Ochraqualfs).

NICOBAR SEQUENCE

Nicobar upper series (N.I)

Comprises very deep, well drained dark reddish brown soils occurring on steep slopes of medium hills. The texture of the surface soil is loam and sub-soil is clay loam. The soil is moderately eroded and is under mixed deciduous forest (Typic paleudalfs).

Nicobar mid series (N.II)

Comprises very deep, moderately well drained, dark yellowish brown soil occurring on strongly slopping mid-slopes of medium hills. The texture of surface and sub-soil are clay loam. The soil is slightly eroded and is under mixed deciduous forest vegetation (Typic Hapludalfs).

Nicobar valley series (N. III)

Comprises very deep, imperfectly drained olive brown soils occurring on very gently sloping valley lands. The texture of surface sub-soil is clay loam. Soils are slightly eroded and under mixed forest vegetation (Typic Ochraqualfs).

Soil sampling

Soil samples were collected for analysis as per the standard procedure outlined in the Soil Survey Mannual of All India Soil and land use Survey, Indian Agricultural Research Institute (1970).

Methods of Analysis

Mechanical Composition :

International Pipette method was followed for obtaining mechanical constituents of soil (Piper, 1966).

Loss on Ignition

By igniting a weighed quantity of oven dry soil in a platinum crusible for 30 minutes on bunsen flame (Bear, 1955).

Water Holding Capacity

Water holding capacity of the soils were determined as per the procedure described by Piper (1966) using the Keen-Raczkowski box.

Moisture equivalent

Moisture equivalent of soils were determined by using soil centrifuge at controlled speed of 2440 r.p.m. following the procedure described by Piper (1966).

Computation of ratio and Erodibility indices

Dispersion ratio was calculated according to Middleton et al. (1934) dividing the suspension percentage by total silt + clay.

Erosion ratio

Erosion ratio was calculated by the methods suggested by Middleton et al. (1932) by dividing the dispersion ratio by clay and moisture equivalent ratio.

Measurement of Soil erosion

Soil and run off loss were estimated by field experiment suggested by Sen *et al.* (1944). A wooden bottomless box, 18" x 18" x 8" provided with 1" wide gutter along one side and 2" below the super edge of the side, has been used for the measurement. The gutter is made slightly sloping to facilitate a free passage of the run off along with the eroded soil in order to prevent the overflow of the run off which otherwise may be caused by the accumulation of the eroded material. An outlet tube kept flush with gutter is also provided.

A representative site is selected and carefully denuded of the natural vegetation (grass). Disturbance to the soil is kept at the minimum. Slope of the land is measured. At the site selected the box is placed and its inner boundary marked with a knife and covered with a plate to protect the surface soil from being disturbed during digging. Carefully fix the box in position and sunk by removing the extra earth from sides. Metal cover is then removed.

When the box is fixed in position a bent glass tube is fitted through a hole at one end of the gutter by means of sealing wax. The other end of the bent glass tube is connected by rubber tube with another glass tube leading through a rubber cork into the reservoir in which the run off with the eroded material is collected. A rain gauge is placed nearby on land. After the precipitation the run off with the eroded soil is collected. Eroded material is filtered and measured.

Chemical Analysis of Soil

Organic Carbon

The wet digestion method of Walkly and Black was followed (Piper 1966).

Organic Nitrogen

Digestion was carried out according to Kjeldahl method and the digested material was distilled with freshly ignited magnesia, the liberated ammonia was absorbed in 4% boric acid containing mixed indicator (5 drops of bromo cresol green and 1 drop of methyl red). The absorbed ammonia was directly filtrated with decinormal hydrochloric acid (Metson, 1956).

Chemical Analysis of the Clay fractions

Separation of clay

Clay fraction was separated by the standard procedure of Jackson *et al*. (1949).

Fusion Analysis

Fusion analysis of soils was carried out by the standard method as described by Bear 1964. Following soil constituents were determined in the fusion extract.

Silica

The silica was rendered insoluble by repeated dehydration on sand bath and weighed as SiO_2 and in the filtrate after determination of silica, the following estimations were carried out (Bear, 1964).

Sequi-oxides

The sequioxides were precipitated 1 in 150 cc of the filtrate with ammonia. The precipitate was washed free of chlorides with ammonium nitrate, dried, ignited and weighed as sesquioxides (Bear, 1964).

Calcium

In the filtrate after removal of sesquioxides and elimination of manganese (Piper, 1966) Calcium was precipitated as Calcium Oxlate and titrated with standard Potassium Permanganate (Jackson, 1958).

Magnesium

Magnesium was determined in the filtrate after removal of Calcium by precipitating as magnesium - ammonium phosphate, filtered, ignited and weighed as $Mg_2P_2O_7$ (Bear, 1955).

Iron

Iron was estimated colorimetrically in a suitable aliquot of the hydrochloric acid extract, after separation of silica by sodium salcylate method as modified by Scott (1941). The intensity of colour was measured with photo-electric colorimeter.

Incidentally, it is mentioned that in all the samples iron was, estimated volumetrically, first by reducing the iron with stanous chloride and titrating with the decinormal potassium dicromate using phenylamine as internal indicator. Both the values agreed well.

Aluminium

Aluminium was estimated colorimetrically in a suitable aliquot of fusion extract by the method of Robertson (1950), using thiogly-collic acid for reduction of iron andaluminium for the development of colour with aluminium as complex. The colour intensity was measured with photoelectric colorimeter.

Titanium and Manganese

A suitable aliquot of the hydrochloric acid extract was made free of chlorides by fuming concentrated sulphuric acid (A.R.). In a portion of this, titanium was estimated colorimetrically after development of colour with hydrogen peroxide and measuring intensity of colour with photoelectric colorimeter.

In a second portion of this, permanganate colour was developed with potassium periodate after addition of glacial phosphoric acid (Bear, 1955) and colour intensity was noted with photoelectric colorimeter.

Potassium

A suitable aliquot of hydrochloric acid extract was evaporated to dryness, gently, ignited and the residue was taken up in hot water, filtered and made to volume. Potassium was estimated in the water extract with the help of EEL Flame photometer.

Free Oxides of Iron, Aluminium and Manganese in the soils and clays.

Sodium hydrosulphate method as described by Mackenzie (1954) was followed for removal of free oxides.

Soil reaction

It was determined by glass electrode in 1:2.5 soil suspension with the help of Beckman pH meter (Piper, 1966).

Cation Exchange Capacity :

Cation Exchange Capacity determined by Schollenberger's method of leaching with neutral normal ammonium acetate solution as described by Metson (1956).

Exchangeable bases

Ammonium accetate leachate was evaporated, ignited and after the removal of iron, aluminium, manganese, phosphate, ammonium salts and silica, exchangeable cations were determined in the extract Metson (1956).

Exchangeable Calcium and Magnesium were determined by Versenate titration method described by Metson (1956). Exchangeable Sodium and potassium were determined with the help of flame photometer.

Cation Exchange Capacity of clay fractions

The micro method for the determination of cation exchange capacity of clays, as described by Mackenze (1951) was followed.

Available Phosphorus

Available phosphorus was determined by following Bray's method No. I (Bray and Kurtz, 1945).

Available Potassium

Available potassium was determined following flame photometer method (Troth and Prince 1949 and Stanford *et al.*, 1949) as quoted by Gilbert R. Muhar *et al.*(1965).

Minerological Analysis

A weighed quantity of fine sand was treated with 10% hydrochloric acid (Chakravarti, 1943) to remove the free oxides of coatings on the particles. The fine sand fractions separated using bromoform (sp. gr. 2.86). The samples were then made free of bromoform, dried and weighed.

Each of the fraction of light and heavy minerals was mounted on slide with Canada balson and the dominating minerals were identified with the help of petrographic microscope. The frequency, of their occurrance was calculated from actual counting of the grains.

Minerological Analysis of the clay fraction

1. X-ray Diffraction

X-ray ~~Dxffxxxkx~~ powder diffraction method was used to identify the clay fraction.

It is well known that when a beam of X-ray falls on a powder specimen, it is diffracted according to Bragg's law, i.e.

$$2\ d\ \mathrm{Sin}\ \phi = n\ \lambda$$

where d is the interplaner spacing, between successive planes of atoms in the crystal, ϕ is the Bragg angle i.e. the angle between X-ray beam and their atomic planes. λ is the X-ray wave length and n is an integer. Thus by calculating different $(\frac{d}{n})$ values from the diffracted powder lines and then comparing the value with ASTM cards, the minerals were identified.

First the clay fraction was grinded in an agate morter, which it is sufficiently powdered, the sample was then poured in a capillary tube of diameter 0.3 m/u and packed closely. The closely packed portion of the specimen was then cut and mounted to the Debye Schoner Powder Camera. In the present investigation, Phillips Camera was used. After centering, it is loaded with X-ray films in the dark room. The loaded camera was then placed for X-ray exposure. Here Fe K radiation was used with Mn filter.

After the film being sufficiently exposed, it is developed and then dried in air. The distances between the successive diffraction lines were then measured. From the measured distance'd' values were calculated. The 'd' value were then arranged in order of decreasing intensity of the diffracted lines, and the minerals were identified.

2. Differential Thermal Analysis

Delta therm is differential thermal analysis apparatus, designed to record differential thermal curves on samples simultaneously, with automatic programming of the run. Delta therm model D 2000 of Technical Equipment Corporation, USA was used for the purpose.

Thermal analysis provides qualitative and quantitative information on materials through detection of physical and chemical transition during controlled temperature change. DTA differential thermal analysis compares the temperature of a specimen with a thermally inert reference material. Thisis used to supplement the results obtained by X-ray analysis. Delta therm system, D 2000 basic unit provides 1. Temperature programming with $\pm$ 2% linearity at 100 or more discrete heating rates between $0^{o}C$ to $20^{o}C$ and $20^{o}C$ per minute. Four channel recording with electric sensitive paper for clean trouble free perfomance is provided.

3. Identification of clay mineral by staining test

The benzidine test for untreated materials and the malachite green for acid treated materials are valuable techniques for the identification of clays in soils and rocks. Application of benzidine test to acid treated materials is of little value, and use of SAFRANINE "Y" and malachite green with untreated materials is useful only to demonstrate original acidic condition of the constituent clays (Richard, C. Mielenz, *et al*., 1950).

Anomalous results some times are obtained from the tests. Various non clay substance may cause or inhibit staining reactions; and some clays fails to react in a characteristic manner for a yet inexplicable reasons. However, anomalous reactions are infrequent and usually are reached by comparison of results of staining tests with data assembled on the material from microscopical and other observations.

RESULTS AND DISCUSSION

Three soil sequences have been studied under the present investigation viz., (1) Diglipur Sequence, (2) Rangat Sequence, (3) Nicobar Sequence. For selection of profile sites special care has been taken in view of the Agricultural development needs of the Island. It is, therefore, considered appropriate to select the investigation sites in Land capability classes II, III and IV, which are suitable for Agricultuural development in hills of medium elevation. (Soil Survey Mannual 1970, Mannual on conservation of soil and water, USDA 1964). While considering the Land capability classes land suitability class also was considered in view of the availability of intrastructure for development. This necessitated selection of sites in the vicinity of sea coast where transport and communication systems are improved (FAO Report 45 (1975). Each of these is a separate study by itself. For the sake of better presentation and discussion each of the sequence is dealt with separately and later on, a general discussion has been furnished to have an inter-related appraisal of both.
The results and discussion are, therefore, given in the following order :

A. Diglipur Sequence

B. Rangat Sequence

C. Nicobar Sequence

D. General Discussion.

Under each of the three sequences, the data on morphology of profiles, physical, chemical and minerological properties of the soils as well as discussion thereon are presented.

A. DIGLIPUR SEQUENCE

(1) Morphology of the profiles

Profiles distinguish themselves from one another in many features.

The soil sites selected at upper slopes, mid-slopes and valleys of medium hills were occurring in different locations of a toposequence within a reasonable distance from one another (Plate V & VI).

The striking feature of this sequence is the presence of three diverse types of soils each gradually merging from dark reddish brown to Light Olive brown through transitional shade dark yellowish brown.

Morphology of Soil Profiles

Representative three profiles of three toposequences were selected after reconnaisance study of the area and the morphological investigation of the soil profiles was done as per the Soil Survey Manual of All India Soil and Land Use Survey Organisation, Indian Agricultural Research Institute (1970). In the sequence, each profile represents a particular situation and

PLATE V- DIAGRAMATIC PRESENTATION OF THE LANDSCAPE AND PROFILE SITES OF DIGLIPUR SEQUENCE

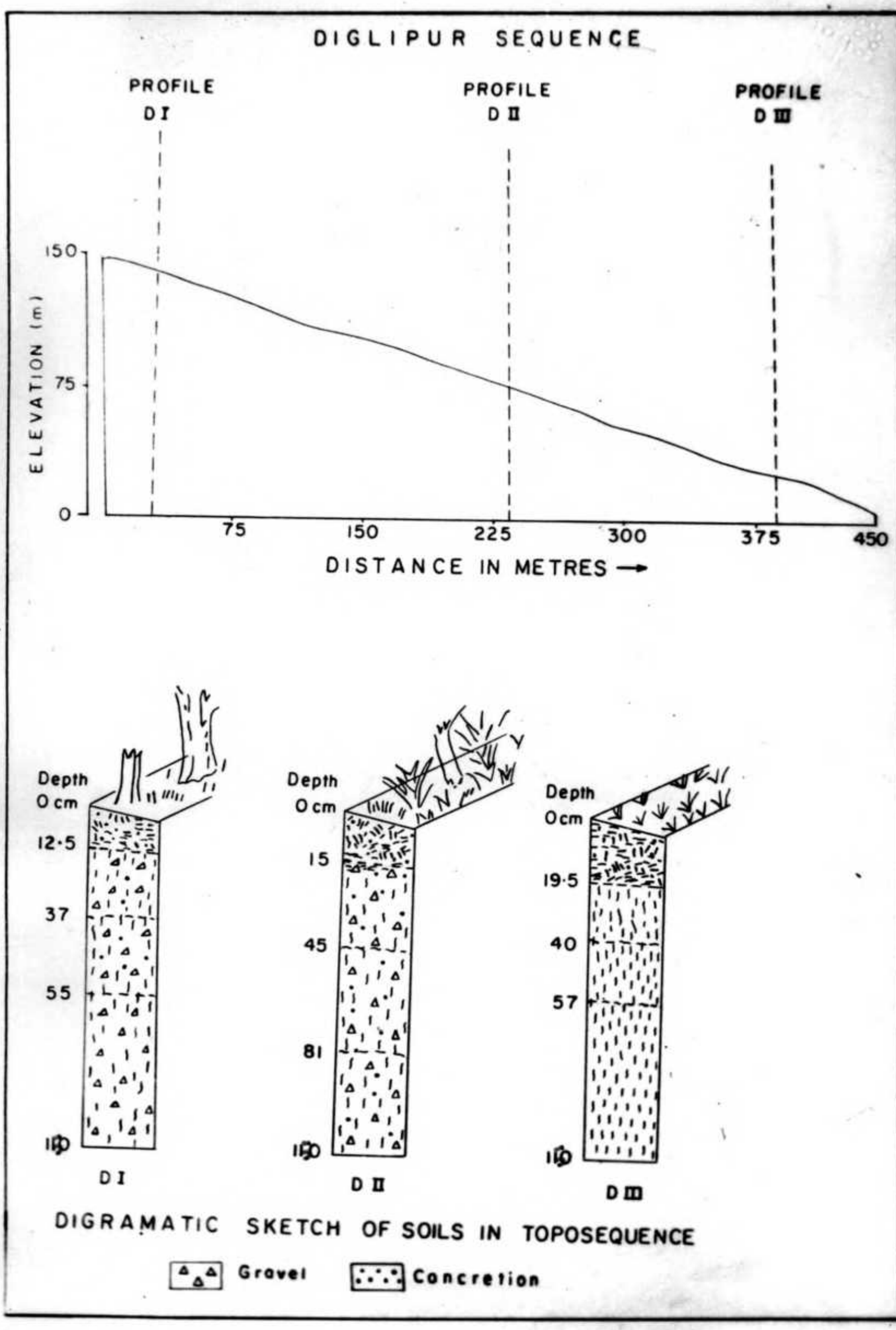


PLATE VI - DIAGRAMATIC SKETCH OF SOILS IN TOPO-SEQUENCE - DIGLIPUR SEQUENCE drainage condition. Profiles described are on a single slope. The relative positions and the depth of the profiles are represented diagramatically.

Diglipur Sequence

Diglipur upper Series (D.I.)

Comprises very deep, well drained soils derived from sandstone and shale parent material occurring on steep (25-33%) upper slope of medium hills. The pedons have dark reddish brown to reddish brown, medium textured A horizon grading to reddish brown to yellowish red moderately fine textured B horizon. The soils are moderately eroded.

Diglipur upper series is a member of fine clayey mixed hyper thermic family of Mollic Hapludalfs.

Typifying Pedon : Diglipur upper loam (colours are for dry soil unless otherwise noted).

Horizon	Depth (cm)	Description
A1	0-10.5	Dark reddish brown (5YR 3/3 moist) loam; moderate, medium, granular structure; slightly hard, friable, slightly sticky, slightly plastic; abundant, fine and medium roots; many fine pores; abrupt, wavy boundary.

Horizon	Depth (cm)	Description
B1	10.5-37	Reddish brown (5YR 4/3) sandy clay loam; few, medium, distinct 5YR 6/6 mottles; moderate, medium sub-angular blocky structure; hard, friable, very sticky, very plastic; thin patchy clay skins; common, fine roots follow ped faces; few fine pores; few iron and manganese concretions, clear wavyboundary
B2t	37-55	Light reddish brown (5YR 6/3) clay loam, mottles with light brown (7.5YR 6/4); massive breaking to weak, fine, and medium, sub-angular blocky structure; friable, slightly hard, very sticky, very plastic; thin patchy clay skin on ped faces; common fine pores in peds; partly weathered fragments of soft sandstone present, clear wavy boundary.
B3t	55-150	Yellowish red (5YR 4/6), gravelly clay loam; common, medium and distinct pink white (7.5YR 8/4) mottles; massive breaking to weak, firm, medium sub-angular blocky structure; slightly hard, firm, sticky, plastic; thin continuous clay skin on ped faces; few fine pores in peds; partly

Horizon	Depth (c m)	Description
		weathered few small fragments of softs sandstone and shale parent material present.

Range in characterisatics

Solum depth is very deep. Surface soil colour ranges from dark reddish brown to reddish brown in hue 5YR with value 3 to 4 and chroma 3 to 4; texture of the fine earth fraction ranges from loam to sandy clay loam.

Sub-soil colour ranges from reddish brown to yellowish red in hue 5 YR, with values 4 to 6 and chroma 3 to 4; texture ranges from clay loam to clay. The clay content gradually increases with depth and reaches maximum in B3t horizon.

Drainage and permeability

Well drained. Permeability is moderate. Run off is moderately rapid.

Use and Vegetation

Mostly under mixed deciduous forest.

Distribution and Extent

Occur extensively on upper slopes of medium hills in North Andaman.

Series established and type location

Diglipur upper series : 170 km. north of Port Blair, eastern side of Port Cornwallis $13^{o}15'$ north latitude and $93^{o}1'$ east longitude at an elevation of 145 m. M.S.L.

Diglipur mid Series (D.11)

Comprises very deep, moderately well drained soils derived from sandstone and shale parent material occurring on strongly sloping (10-15%) mid-slope of medium hills. The pedons have dark yellowish brown moderately fine textured. A horizon grading to yellowish brown to olive gray, moderately fine textured B horizon. The soils are moderately eroded.

Diglipur mid series is a member of fine clay mixed hyper thermic family of Typic Hapludalfs.

Typifying pedon : Diglipur mid clay loam (colours are for dry soils unless otherwise noted).

Horizon	Depth (cm.)	Description
A1	0 - 15	Dark yellowish brown (10YR 4/4 moist) clay loam; moderate sub-angular clods breaking to fine and very fine granules; friable, moist, slightly hard; abundant roots; few worm casts and openings, numerous medium and fine pores, clear smooth boundary.

Horizon	Depth (c m.)	Description
B1	15-45	Yellowish brown (10YR 5/4) clay loam; weak medium, subangular blocky; slightly firm, slightly hard; thin patchy clay skins on horizontal and vertical ped faces; common, medium fine roots; common fine pores, diffuse and wavy horizon.
B21t	45-81	Brown (7.5Yr 5/6 clay loam; medium, fine, subangular blocky structure, slightly firm; faint very pale brown (10Yr7/3) mottlings on ped faces; thin patchy clay skins; few fine roots; few, partly weathered soft parent material, common fine pores, clear wavy boundary.
B22t	81-150	Strong brown (7.5YR 5/6) clay loam, few, faint, light yellowish brown (2.5YR 6/4) mottlings; moderate fine subangular blocky structure; slightly hard, friable, sticky, slightly plastic; thin patchy clay film on ped faces; few fine pores; few fine ferrugenous concretions. Partly weathered soft sandstone parent material present.

Range in characteristics

Solum depth is very deep. Surface soil colour ranges from dark yellowish brown to yellowish brown in hue IOYR with value 3 to 4 and chroma 4 to 5; texture ranges from clay loam to sandy clay loam. Subsoil colour ranges from yellowish brown to light brownish grey in hue 10YR with values 5 to 6 and chroma 2 to 4; texture is clay loam. The clay content gradually increases with depth and reaches maximum in B3t horizon.

Drainage and permeability

Well drained ; permeability moderately slow; Run off is moderately rapid.

Use and Vegetation

Mostly under horticultural crops, and other homestead crops.

Distribution and Extent

Occur extensive on mid-slopes of medium hills in North Andaman islands.

Series established and type location

Diglipur mid series : 170 km north of Port Blair, eastern side of Port Cornwallis; $13^{o}15'$ north latitude and $93^{o}1'$ east longitude at an elevation of 75 m.M.S.L.

Diglipur Valley Series (D. III)

Comprises very deep, imperfectly drained soils derived from colluvial and alluvial material occurring on very gently sloping (1-3%) Valley land. The pedons have very dark grayish brown, moderately fine textured A horizon grading to light brownish gray to gray, fine textured B horizon. The soils are moderately eroded.

Diglipur Valley series is a member of fine clayey mixed hyperthermic family of Typic ochraqualfs.

Typifying pedon — Diglipur Valley clay loam (Colours are for dry soils unless otherwise noted).

Horizon	Depth (cm.)	Description
Ap	0-19.5	Light olive brown (2.5Y 5/4 moist) clay loam; moderate, medium, subangular blocky structure; very hard, very sticky, very plastic; abundant fine roots; worm caste, common medium, fine pores, vertical and horizontal cracks; clear smooth wavy boundary.
Blt	19.5-40	Light brownish gray (10 YR 6/2 moist) clay, with prominant spots of reddish yellow (7.5YR 6/8); strong, medium, angular blocky structure; wedge shaped peds with shiny faces; very hard, very firm, very sticky and very

Horizon	Depth (cm.)	Description
		plastic; thin continuous pores in peds; few fine roots; vertical and horizontal cracks exist, clear, wavy boundary.
B21t	40-57	Light olive gray (5Y 6/2 moist) clay; strong, medium, angular blocky structure; very hard, very firm, sticky, plastic; thin patchy, clay skin on ped faces; few, fine pores in peds; mottled with faint pinkish gray (7.5YR 6/2) and reddish yellow (7.5YR 8/6); clear wavy boundary.
B22t	57-150	Gray (5Y 6/1 moist) clay; strong, medium, angular blocky structure; very hard, very firm, sticky, plastic; continuous thin clay skins on ped faces; few, fine, pores.

Range in characteristics

Solum depth is very deep. Surface soil colour ranges from very dark grayish brown to dark grayish brown on hue 2.5Y with value 3 to 5 and chroma 2; texture of the fine earth fraction is clay loam. Subsoil colour ranges from light brownish gray to gray in hue 10YR 2/6 to 5YR 6/1 with value 6 and chroma 1 to 3; texture is clay. The clay content gradually increased with depth and reaches maximum in B22t horizon.

Drainage and permeability

Imperfectly drained; permeability moderately slow to slow; run off is moderate.

Use and Vegetation

Mostly under paddy and other field crops.

Distribution and Extent

Occur extensive on Valley lands in North Andaman Islands.

Series extablished and type location

Diglipur Valley series : 170 km. north of Port Blair, eastern side of Port Cornwallis; 13°15' north latitude and 93°1' east longitude at an elevation of 7m. M.S.L.

NOTE : Soil remains under excessive moisture regime from May to November.

Dark reddish brown colour in the upper slope turns more darker as it comes down the slope. May be due to drainage condition. One of the clues to soil, air and water relationship is the colour of the sub-soil. A well oxidised soil has often bright red colours. More well drained the soil more reddish in colour and turns gray as the drainage becomes poorer.

Texture turns heavier from upper slope to valley. Structure varies from moderately fine to fine textured down the slope. Stickiness and plasticity of the soils are on the increase from upper to lower situation.

Depth of the solum increases from upper to lower situations. Surface soil depth is progressively on the increase from upper slope to lower situation. Topography influences to a great deal in extent, character and depth of the profiles. This is corroborated by the observation of Norton and Smith (1930) on the influence of topography on the profile character in the soils of Illinois. This is common to all catenary soils discussed earlier.

Another point is the drainage condition. The restricted drainage and high water table have brought about greater intrazonal characters than zonal ones (Agarwal et al. 1957).

Valley soils present cracks vertically and horizonally. Milne (1936) also described the light texture in victoria soil and stated that top layers of soils of upper situation owes its origin to run off flowing laterly through the surface and carrying with it the clay. High intensity precipitation together with undulating topography do not allow all the water entering the soil to percolate downwards so that some finds its way laterally (run off) and it is a regular feature in tropical and sub-tropical profiles (Robinson 1939). Such variation in the soils occurring along the slope throughout the Andaman and Nicobar Islands provide an example of Milne's (1935) 'Catena'.

2. Colour of the Soils and their clay fraction

Mohar and Van Barren (1954) also observed in Indonesia which maintains geological continuity with Andaman and Nicobar

Island, the face slopes with good drainage are often characterised by oxidising conditions which causes rapid decomposition of organic matter and result in the formation of Yellow or reddish soils, while the back slopes with poor drainage display grey humic dark coloured soils. The well drained hill tops, on the contrary, are characterised by an oxidising environment and soils that are coloured by iron hydroxides.

Oxidation of organic matter by H_2O_2 (Table 1) has not shown any perceptible colour change.

The organic matter content increases towards upper horizons and gives these soils darker shades with increasing degree of humification. When soils were subjected to pre-treatment with HCl to decompose the carbonates followed by treatment with H_2O_2 dark colour was reduced. Soil reaction and cation exchange capacity having calcium in the exchange complex may also appear to give dark colour to the soils in the presence of organic matter. Presence of Manganese dioxide may also cause dark colour to these soils. There is little change in the chroma and value which show that organic matter has not contributed much to the colour of the soil. Slight change in the chroma is noticed in the surface soils of the three soil series. There is a tendency of colour change from darker to grayish shades.

<u>Soil colour in relation to free oxides</u>

Removal of free oxides from the soils generally reflects a change in the chroma in all the soils (Table 1). The soils loose

Table 1. Colour of the soils

DIGLIPUR SEQUENCE

Soil series	Depth (cm.)	Field observation	On air dried	On removal $CaCO_3$ and organic matter	On removal of free oxides
DI	0-10.5	5YR3/3	5YR3/2	5YR3/2	5YR4/1
	10.5-37	5YR4/3	5YR4/2	5YR4/2	5YR4/1
	37-55	5YR6/3	5YR4/1	5YR4/1	5YR4/1
	55-150	5YR4/6	5YR5/6	5YR4/6	5YR4/2
DII	0-15	10YR4/4	10YR4/4	10YR4/4	10YR5/2
	15-45	10YR5/4	10YR6/4	10YR5/4	10YR5/2
	45-81	7.5YR5/4	7.5YR5/3	7.5YR5/3	7.5YR5/1
	81-150	7.5YR5/6	7.5YR5/4	7.5YR5/3	7.5YR5/2
DIII	0-19-5	2.5Y5/4	2.5Y4/2	2.5Y4/2	2.5Y4/2
	19.5-40	10YR6/2	10YR6/2	10YR6/2	10YR7/1
	40-57	5Y6/2	5Y6/2	5Y6/3	5Y6/1
	57-150	5Y6/1	5Y6/1	5Y6/1	5Y6/1

the red and Yellowish colour by turning towards grayish tinge. The colour of the soils of the sequence D1, DII and DIII become dark reddish brown, dark yellowish brown, and light olive brown. Free oxides of iron therefore, appear to play an important role in the red and yellowish colours of the soils. The mineral responsible for most of the inorganic colouration of freely drained soils of high situation may be goethite which has colours that range from reddish brown to yellow with an increasing degree of hydration. The highly hydrated yellow and yellowish brown forms may be due to limonite.Gray and olive coloures occurring in the soils of lower situation and down below the profile possibly, due to impeded drainage, wet situation and originate through the presence of iron in the reduced or ferrous state. The grayish colour may originate through lack of alteration of gray and white parent material, as a result of removal of iron leaving uncoated light coloured minerals such as quartz, feldspars etc. which are present in these soils. Free iron oxides are more active in well drained soils of upper regions i.e. DI and DII, and impart colour to the soils (Kelly et al., 1939; Joshi, 1945; Karim, 1935; Fitz Patrick E.A. 1971).

Colour of the clay fraction

Study of the variation in the colour of clay has given the indication that the change is not significant though there is a tendency of change towards lower chroma (Table 2). It may be probable that the iron oxides and organic matter may dominate with the surface areas of the clay fraction depending on the degree of hydration. Similar results were reported by Kelly *et al.* (1939) on the colour of California soils suggesting that free hydrous oxides of iron are the common constituents of the soils to which red and yellow colours are imparted.

Table 2. Colour of the clay fraction

DIGLIPUR SEQUENCE

Soil series	Depth (cm.)	Original	On removal of free Oxide
DI	0-10.5	5YR3/4	5YR3/2
	10.5-37	5YR4/4	5YR4/3
	37-55	5YR4/2	5YR4/1
	55-150	5YR4/8	5YR4/6
DII	0-15	10YR4/4	10YR4/3
	15-45	10YR5/8	10YR5/3
	45-81	7.5YR5/4	7.5YR5/2
	81-150	7.5YR5/3	7.5YR5/2
DIII	0-19.5	2.5Y4/3	2.5Y4/2
	19.5-40	10YR6/3	10YR5/2
	40-57	5YR6/4	5Y6/2
	57-150	5Y6/2	5Y6/1

3. Mechanical composition of soils, thickness and regularity

Perhaps it is questionable to consider the thickness of horizons as an important differentiating property but, it is sometimes found fully developed horizons have fairly well defined limits of thickness. Different members of the sequence maintain more or less a uniform pattern of horizon development indicating approximately the degree of development and age of hirozons.

Texture

The importance of texture in the fabric of the mineral constituents of the soil needs hardly any emphasis (Table 3). The texture of the surface soils of upper situation is relatively coarser than the valley soils. The role of water results in differential erosion in different positions and maintains different moisture status within the same soil profiles. The lower members retain more water for more time. Moisture, clay and pH increases down the slope in different members of the sequence whereas coarser particles maintain the opposite trend from DIII to DI and also within the profile.

Significant changes in the distribution of mechanical constituents of surface soils in various members of the sequence can be seen at Table 3. This brings out the diversity in the mechanical composition and represents a typical gradational pattern which follows the topographic sequence. Upper slope soil is considerably high in coarse constituents as expected due to the lateral transport of the finer material from higher slope to valley. The surface horizon of lower members have their origin partly from the transported finer materials from upper reaches.

Table 3. Mechanical Constituents of soils of Diglipur Sequence

(Expressed in percentage of oven dry basis)

Geomorphic unit	Soil series	Horizon	Depth (cm)	pH 1:2.5	Organic carbon	Gravel	Coarse sand (2-0.2) mm	Fine sand (0.2-0.02) mm	Silt (0.2-0.02) mm	Clay (< 0.002) mm
Medium Hill Upper Slope	DI	AI	0-10.5	5.8	0.76	3.15	9.15	32.25	29.76	28.84
		B1	10.5-37	5.9	0.43	6.28	5.86	38.9	26.50	28.74
		B21t	37-55	6.0	0.22	18.15	6.17	29.69	25.0	39.14
		B22t	55-150	6.1	0.21	26.25	6.43	30.04	23.0	40.53
Medium Hill Nid Slope	DII	A1	0-15	5.9	0.75	2.21	8.19	30.41	28.10	33.30
		B1	15-45	5.9	0.41	3.15	8.7	28.30	27.1	35.9
		B21t	45-81	6.0	0.20	6.35	13.11	22.69	26.0	38.2
		B22t	81-150	6.1	0.14	7.05	10.45	23.35	26.1	40.1
Valley	DIII	A1	0-19.5	6.0	0.65	-	3.61	22.70	37.0	36.69
		B1t	19.5-40	6.2	0.41	-	2.82	19.88	35.0	42.30
		B21t	40-57	6.5	0.22	-	2.60	16.21	33.2	47.99
		B22t	57-150	6.5	0.15	-	2.25	17.16	32.1	48.49

Fine sand shows gradual decrease down the slope. Except in Diglipur valley series (DIII), silt decreases not only down the slope but also down the profiles. The increased percentage of silt in the upper horizons of the slope members indicate that the silt is the product of weathering <u>in situ</u> (Brown & Throp, 1942). The low content of silt in the up land soils is a characteristic shown by many tropical soils (Radwanski & Ollier, 1959).

The higher percentage of silt content in the valley profile DIII is possibly due to the process of deposition from upper reaches.

The clay content of the surface soil shows regular gradation according to the topography. Clay content increases gradually and regularly from the upper slope member to the valley soils. The clay content gradually increases within the profiles. Upper soils have more open structure and excessive drainage. Profiles developed under well drained conditions are subjected to rapid drainage and consequent mechanical eluviation of clay. This reasoning holds good also for profiles DII and DIII. There is regular increase in clay content down the slope, reaching maximum in the valley profiles (DIII). This is a clear evidence of the lateral translocation of the finer particles from the upper situation to the lower slope. Similar results were recorded by various workers, wherever different soil types are related to topographic sequence (Brown & Throp,1942, Desai, 1942). Morison (1949), in his catenary studies of Anglo-Egypsian soils, indicated three complexes, each associated with topography. The complexes are (1) Eluvial complex, occupying the higher level site which provides the material, from which other complexes are built up; (2) colluvial complex which occupies the slope and receives material from eluvial complex and loses some of it to illuvial complex; (3) Illuvial complex occupying the low level sites. Accordingly the upland profile (DI) can be under eluvial complex, mid-slope (DII) soils under colluvial complex and valley soils (DIII) under illuvial complex.

Mechanical constituents of the soils also correspond to the observation of Nye 1954, Agarwal et al. (1957) for catenary soils in relation to topography. They closely resemble to a great extent to the gradation in composition of catenary soils of New South Wales as reported by Hallsworth et al. (1952) and Brown and Thrlandop (1942).

In brief the mechanical constituents and pH are closely related to the toposequence.

Organic Carbon

The organic carbon shows increase in upper members of the profiles in the toposequence. Organic carbon content down the slope varies from 0.76 to 0.65 per cent. Higher percentage of organic carbon as compared to cultivated soil is observed in profile DI and DII. The decrease in the organic carbon down the catena as seen in DII is probably due to heavy texture, more moisture which lead to more biotic activity. These results are also in conformity with the trend of organic carbon reported by Muir et al. (1957) and Raychaudhuri et al. (1943).

Organic Nitrogen

Nitrogen content of the soils (Table 4) maintains the same trend of distribution of organic matter. Effect of intensive cultivation might be having its influence in the reduction of organic matter particularly in soil profile DIII.

Table 4. C/N Ratio of the soil.
(Expressed in percentage on oven dry basis)

DIGLIPUR SEQUENCE

Soil series	Depth (cm)	Organic carbon	Organic nitrogen	C/N Ratio
DI	0-10.5	0.76	0.054	13.9
	10.5-37	0.43	0.034	12.5
	37-55	0.22	0.021	10.3
	55-150	0.21	0.021	9.8
DII	0-15	0.75	0.058	12.8
	15-45	0.41	0.032	12.6
	45-81	0.20	0.019	10.1
	81-150	0.14	0.014	9.8
DIII	0-19.5	0.65	0.047	13.82
	19.5-40	0.41	0.032	12.5
	40-57	0.22	0.021	10.3
	57-150	0.15	0.015	9.7

Carbon-nitrogen ratio

The C/N ratios do not show much variation in the surface soils of the sequence. But as a whole, there is wide variation in maximum and minimum values viz., 13.9 to 9.7. The results also bring out the relationship in the soil sequence. As the drainage becomes poorer, the transition to sub-soil becomes sharper and ratio narrower. This may be due to the fact that surface layers may contain some of the humified material. The ratios are in conformity with the findings of Agarwal et al. (1957) in their studies on catenary soils.

Cation Exchange Capacity and Exchangeable Cations of the soil

The soils of this sequence differ in their cation exchange capacity (Table 5) from the upper member DI to lower valley series DIII. The cation exchange capacity shows an increasing trend from the Diglipur upper series (D1) to Diglipur (DIII) series. The cation exchange capacity increases regularly along the slope pari passu. The increase in clay content of the soils and the rate of increase is higher than the amount normally expected from the amount of clay, this gradation of variation follows the topographic sequence. This variation may be due to the nature of the clay and amount of clay minerals present in different soils. This is confirmed by the data on cation exchange capacity of clay and X-ray diffraction studies of the clay fractions.

General increase in the cation exchange capacities particularly of the sub surface layers also corresponds to the silica-sesquioxide ratios of the clay fractions.

Table 5. Cation Exchange capacity and exchangeable cations of the soils.

(Expressed in me.percent on oven dry basis)

DIGLIPUR SEQUENCE

Soil series	Depth (cm)	C.E.C. m.e. 100 g	Ca^{++}	Mg^{++}	Na^{++}	K^{+}	Total	Base saturation per cent
Diglipur upper series (DI)	0-10.5	21.56	10.5	6.03	0.41	0.24	17.18	79.68
	10.5-37	19.25	9.6	6.13	0.29	0.58	16.6	86.23
	37-55	26.85	13.5	8.94	0.33	0.03	22.8	84.91
	55-150	27.31	14.4	8.66	0.26	0.58	23.9	87.51
Diglipur series (Mid) (DII)	0-15	23.0	11.7	7.44	0.35	0.61	20.1	87.39
	15-45	21.3	10.5	6.78	0.30	0.62	18.1	84.97
	45-81	24.8	13.0	7.77	0.31	0.02	21.1	85.08
	81-150	24.06	13.10	7.08	0.22	0.90	21.3	88.52
Diglipur Valley Series (DIII)	0-19.5	21.15	10.56	6.04	0.32	0.74	18.2	86.05
	19.5-40	26.43	13.82	7.03	0.46	0.81	22.3	84.37
	40-57	31.02	17.81	9.01	0.54	0.65	28.1	90.58
	57-150	30.70	16.61	10.02	0.32	0.06	27.01	87.98

Exchangeable bases

Upper slope members by virtue of their topographic situation, are not base saturated. Ac Aleese and Mc Conaghy (1957) observed under imperfect drainage conditions, there is a reduction in the losses of weathering products. This may result in the exchangeable cation content being maintained at a relatively higher level throughout the profile. This appears to hold good in the soils under poor drainage in present investigation.

Exchangeable calcium is predominant base in all the soils. The exchangeable calcium percentage shows an increasing trend from the upper member D1 to lower member DIII.

Exchangeable magnesium is second dominant cation in the exchange complex. Exchangeable magnesium behaves just like exchangeable calcium in the surface soils. It increases gradually down the slope as well as down the profiles.

Magnesium assumes important position in the exchange complex. This may be due to the fact that calcium in exchange complex is more readily replaced by hydrogen ion than magnesium and thereby increasing the saturation with magnesium. The gradual replacement of calcium by magnesium is reported by Gedroiz (1916). Poor drainage condition enhances markedly the status of magnesium.

Exchangeable sodium which is a minor cation in the soil is much lower in values. Soils of the lower slope members are relatively higher in exchangeable sodium than the upper slope members.

Exchangeable potassium is also a minor cation in the soil and is below 1 m.e. The distribution shows an increasing tendency down the slope from the upper member D1 to DIII. It is probable that it is also related to the drainage pattern of the soil.

Chemical composition of the clay fraction

Chemical composition of the clay fraction is presented in Table 6. It shows differences in the profiles from upper member (DI) to lower member (DII) in the toposequence. The clays from the well drained soils are more sesquioxidic and less silicious as compared to the clays from the imperfectly to poorly drained soils. Thus, increase in silica is accompanied by corresponding decrease in the content of sesquioxides.

Silica

The silica content shows a decreasing tendency from the upper member (DI) to lower member (DIII) in the toposequence. Silica constitutes relatively greater percentage of the chemical constituents. The less silicious nature of the clays of the upper slope member as a result of drainage was recorded by Brown and Throp (1942) in the Miami Catena and in the Catenary soils of Vindhyan plateau (Agarwal et al., 1957) and also in the Norfolk series (Holmes et al., 1939).

Sesquioxides

The difference in the drainage pattern of the toposequence causes variation in the distribution of sesquioxide. The clay of the upper slope members of the toposequence have higher percentage of sesquioxides than the preceding members. The leaching of bases under freely drained conditions leads to instability of more siliceous complex. Thus soils of upper members have lower percentage of silica and relatively higher percentage of sesquioxide than the lower members. Sesquioxides show slight variation within the profile and this variation is more due to the mobility of alumina rather than that of ferric oxide in well drained soils.

Alumina decreases down the slope with corresponding increase in the silica content of clays. It may be mentioned that the clays of upper (DI) and middle (DIII) members are lower in silica and higher in alumina than the lower slope member (DIII) soils of the toposequence.

Ferric oxide shows the increasing trend from the upper member to the lower ones. The lower member shows a certain amount of irregularity in the distribution which may be due to cultivation effect and differential deposition.

Molecular ratio

The molecular ratio given in the Table 6 follow the toposequence. Silica sesquioxide ratio increases as the drainage becomes poorer and varies from the upper slope to lower member (DIII). The higher ratio in the surface of cultivated soils may be due to the translocation of alumina down the profiles. In general, increase in silica-sesquioxide ratio down the slope is mainly caused by the increase in silica content and decrease in

Table 6. Chemical Composition of Clay Fraction. Diglipur Sequence.

(Expressed as percentage on ignited basis)

Name of Series	Depth Cms.	Moisture	Loss on ignition	S_iO_2	R_2O_3	Al_2O_3	Fe_2O_3	TiO_2	MnO	CaO	MgO	K_2O	$\frac{S_iO_2}{R_2O_3}$
Diglipur Upper Series (D I)	0-10.5	7.50	9.70	48.21	35.13	22.17	12.56	0.41	0.26	1.78	2.31	2.81	2.71
	10.5 -37	8.90	10.80	46.70	35.17	23.48	11.16	0.53	0.10	1.85	2.39	2.65	2.59
	37-55	8.62	10.50	47.50	35.12	24.68	9.76	0.68	0.11	2.21	2.21	2.59	2.61
	55-150	8.30	9.60	46.00	36.71	25.68	11.08	0.71	0.24	2.19	2.11	1.21	2.39
Diglipur mid Series (D II)	0-15	8.10	11.76	46.30	35.57	22.18	12.81	0.58	0.23	1.91	2.77	2.31	2.59
	15-45	8.70	12.60	45.20	36.01	22.94	12.36	0.69	0.28	1.82	2.59	2.21	2.56
	45-81	8.92	10.20	47.00	36.26	23.20	12.35	0.71	0.31	2.01	2.54	2.22	2.57
	81-150	9.21	9.50	47.23	35.91	23.64	12.00	0.82	0.21	2.10	2.61	2.08	2.56
Diglipur Valley Series (D III)	0-19.5	8.21	9.31	48.60	34.69	22.71	11.47	0.51	0.14	2.35	3.15	2.01	2.75
	19.5-40	9.31	9.00	49.20	34.10	22.81	10.47	0.57	0.11	2.49	2.98	2.25	2.86
	40-57	10.51	9.10	49.31	34.61	23.10	11.00	0.51	0.09	2.51	3.02	2.60	2.78
	57-150	10.62	10.30	49.79	34.80	22.81	11.66	0.48	0.06	2.61	3.01	2.81	2.77

alumina content. The higher ratios of the sequence show predominance of montmorillonite type clay mineral.

Titanium

Titanium content in the clay fractions are low. The titanium in clay fractions might have been derived from the titanium containing minerals in the soils which by disintegration to finest fractions may have found place in the clay fraction. It may be mentioned that the titanium containing rock minerals are highly resistant to weathering. The trivalent and tetravalent titanium ions have radii close to that of ferric ion. Titanium ion, therefore, is likely to enter in the lattice structure of montmorillinite and illite group by isomorphous replacement (Mitchell, 1955). The titanium distribution in profile is not regular.

Manganese

Manganese content in the soil is low. The distribution of manganese show an increasing trend down the slope except the lower slope member DIII. The distribution of manganese in the clay may to some extent be related to the drainage conditions. In the upper slope members there is a tendency for increase down the depth and decrease with depth in lower slope members. This can be explained as an evidence of the effect of drainage.

Manganese in the clay fractions of the soil is related to some extent to clay minerals present in the clays. Montmorillonite is the major clay mineral present. It is reported that in both the clay minerals montmorillonite and illite there is a possibility of isomorphous replacement by manganese in the lattice structure (Magelschmidt, 1944).

Calcium

Calcium content in the clay fraction shows a gradual increase down the slope. Differential drainage conditions under which these soils are formed may be the reason for this. Calcium follows the toposequence. In the soils calcium content is greater in the sub-soils than in the surface soils and this exhibits the downward leaching of calcium. Lower slope member DIII present a higher status of calcium content than the clays. The lower percentage of calcium may be due to the better drainage conditions under which the soils were formed.

The calcium in the clay fraction probably due to the presence of calcium in the clay complex (Coleman and Jackson, 1945) may be due to the presence of montmorillonite type of clay mineral as stated by Robinson (1949). The latter view of the Robinson has got the evidence in the data on the soils under investigation, i.e. here the major clay mineral is montmorillonite. These Islands having calcareous environment due to the influence of coral formations and deposits of lime mostly under the oceanic influence leads to the presence of calcium and formation of montmorillonite. Grim (1953) observed the calcarious environment is one of the contributory factors in the formation of high calcium in the latter cases.

Magnesium

Magnesium content is relatively higher in all the soils and in the increasing order from upper member (DI) to lower member (DIII). Magnesium follows the similar trend as that of calcium along the slope in the profiles of the toposequence from DI to DIII. The major clay mineral being montmorillonite which themselves contain magnesium (Grim, 1953) have contributed to the total magnesium in the clay.

Potassium

Potassium content of the clay indicates gradation in relation to topography. The clays of better drainage condition in the upper slopes DI and DII shows a decrease in potash down the profile whereas the clays of poorly drained soils show increasing tendency down the profile.

Cation exchange capacity of clay fractions

Cation exchange capacities of clay fractions (Table 7). The CEC maintains a gradation in toposequence. An increasing tendency in the CEC is observed from the upper slope member to the lower slope member. The relatively higher CEC of the clay fraction in all the profiles indicates the type of clay mineral which is identified as montmorillonite.

The CEC is more or less uniform within each profile. This may be considered as an evidence of the uniformity in the clay mineral in all the three profiles. Slightly reducing tendency of CEC in the upper slopes may be due to relatively low predominance of montmorillonite mineral in the soils of upper members. The effect of drainage on the cation exchange capacity of the clay is clearly seen in this sequence. More well drained the soil, less is the CEC and vice versa. Similar observations were made by Gupta (1958) in the catenary soils of vidhyan plateau and by others in some catenary sequence reported earlier.

Table 7. Cation exchange capacity of the Clay Fractions.
(Expressed as m.e. per 100 gm of oven dry clay).

DIGLIPUR SEQUENCE

Soil series	Depth (cms)	Cation exchange capacity
Diglipur upper series (DI)	0-10.5	64.00
	10.5-37	64.21
	37-55	65.31
	55-150	65.12
Diglipur mid series (DII)	0-15	66.20
	15-45	66.40
	45-81	67.20
	81-150	67.80
Diglipur valley series (DIII)	0-19.5	67.30
	19.5-40	68.50
	40-57	69.60
	57-150	69.20

Primary Mineral of the Fine Sand Fractions

Important primary minerals identified in the fine sand fractions of the soils and their frequency of occurrance are presented in Tables 8 and 9. Light mineral constituents form major portion of the fine sand. The distribution pattern is indicative of the small percentage of occurrance of heavy minerals. The parent material is of sedimentary origin and after having weathered from its parent igneous rock was deposited at the present site of investigation through various agencies.

Table 8. Distribution of light and heavy mineral in fine sand fraction (Diglipur sequence)

(Expressed in percentage)

Soil series	Depth (cm)	Light fraction	Heavy fraction
Diglipur upper series (DI)	0-10.5	98.6	1.4
	10.5-37	93.9	6.1
Diglipur mid-series (DII)	0-15	98.1	1.9
	15-45	94.9	5.1
Diglipur Valley series (DIII)	0-19.5	95.2	4.8
	19.5-40	97.3	2.7

Orthoclase feldspar and quartz are often considered fairly resistant to weathering. Use of relatively stable mineral species as a basis for the estimation also entails some difficulties since no mineral is absolutely immobile and stable (Polynov,1944).

Table 9. Mineral composition of the Fine sand fractions
(Expressed in mutual percentages)

DIGLIPUR SEQUENCE

Name of soil series	Depth in (cms)	Light minerals						Heavy minerals									
		Q	OF	PF	M	MM	BM	C	O	Z	T	H	K	S	A	Ap	G
Diglipur upper series DI	0-10.5	58	40		1		1	1	36	28.9	16.1	10.6	1.3	1.0	1.0	3.1	1
	10.5-37	56	37	2		5			43.1	30.9	14.1	10.2	1.7				
Diglipur Mid series DII	0-15	46	46	3		5			37	30.6	6	9.8	1.2	1.1	1.1	3.6	4.6
	15-45	51	45			4			41	28.2	9	10.5	1.9	2.0	1.0	2.1	3.1
Diglipur Valley series DIII	0-19.5	47	48.9	4.1					33.1	41.2	5.3	6.2	6.1	1.		6.1	1.0
	19.5-40	50	55.1	3.9	1.0				32.2	43.7	4.9	5.9	4.3	1.2		7.8	

Reference

Q. Quartz , OF. Orthoclase Feldspar, PF. Plagioclase Feldspar, M. Microcline, MM. Muscovite mica, BM. Biotite, C. Coated, O. Opaque, Z. Zircon, T. Tourmaline, H. Honblende, K. Kynite, S. Sillimanite, A. Anatase, Ap. Apatite, G. Garnet.

Zircon and quartz have been used most frequently because of their apparent relative stability under a wide range of conditions. the Low percentage of plagioclase feldspar bears evidence of dominant mineral and their significance in soil forming processes are discussed below :

Quartz

Quartz constitutes nearly half of the fine sand fractions. In Diglipur upper (DI) and Diglipur mid series (DII) fresh grains of quartz with sharp angular edges are present. They are comparatively of small to big size, whereas the grains present in Diglipur valley profile are mostly smooth and rounded. They are generally more clear and smooth at lower depth than at the surface. This is probably due to the surface creep of parent material as well as soil from the upper slope member.

Feldspar

The next important primary mineral is othoclase Feldspar which is present in all the layers in more or less the same proportion, but differ in the alteration. The orthoclase feldspar in DI is completely altered and extremely weathered, cloudy pitted with alteration products. In DII, 75 per cent of the grains are partially altered and remaining are completely weathered. In DIII soil in the valley only half of the grains are altered. It is observed that alteration of feldspar decreases from upper slope to lower slope members and follows the toposequence. A few grains of plagioclase are present in some of the samples but they are irregular in their distribution. The distribution of microcline is also very few and irregular.

Micaceous mineral

Mica appears to be present in all the soils except in the DIII series occurring in valley with its typical colour of muscovite and interference colours. Muscovite shows increase from Diglipur upper slope member (DI) to Mid series DII and are totally absent in DIII Valley soil.

Opaque minerals

Ferrugenous material in these sand fractions consist mostly of ilmenite and magnatite and are comparatively higher in the upper slope member DI and DII. They are medium to fine size and mostly rounded at the edges. They are often black in colour. A few grains which are light reddish or yellow in reflected light are possibly goethite and limonite. The reddish colour of the soils of upper slope members may be due to the presence of higher iron content. A reduction in the distribution of iron ore is evident in the soils down the slope in toposequence. The presence of opaque minerals is a very useful indication for the weathered nature of the soil (Mohar & Van Baren, 1959).

Zircon

Zircon grains increase gradually down the slope and are proportionately high in valley soil member (DIII) as compared to upper slope members DI and DII. They vary in form and colour. Zircon although occurring in large quantities, is less characteristic as it is a very common mineral as a constituent of greatly different rocks of sufficient acidity. It is often reported the mineral occurs as rather minute crystals. It is, therefore, less useful guide mineral for the origin of soil, even though, with its small crystals, it may be an indication of the texture of the soil (Mohar & Van Baren, 1959). Zircon grains are usually colourless and strictly idiomorphic. Coloured and often rounded zircons on the other hand characterise tertiary sediments.

Tourmaline

Tourmaline shows decrease down the slope. They are mostly platy grains. Tourmaline occurs in different thickness. Marshall recommended tourmaline for use as index mineral.

Honblends

Honblends is present throughout the sequence and shows a general decreasing tendency along the slope. They appear to be foliated and green in colour. This mineral weather fairly rapidly and its extent of weathering is a measure of the degree of weathering.

Kyanite and Sillimanite

Kyanite is distributed throughout the profile in small amount. They are typically bladed crystals with irregular termination. Sillimanite constitutes a very minor fraction of the non-opaque minerals. They are less elongated than kyanite flakes and occurs as prismatic grains.

Apatite

The relative proportion of apatite is higher in the surface layers. They are rounded and pitted in the lower members DII and DIII. Their distribution is relatively very few.

To summarise, the fine sand fractions studied are not typified by specific mineral assemblage but show mixed character.

Quartz present throughout the sequence in more or less the same proportion, but their nature of distribution is also indicative of the soil wash from the upper members down the slope. It is interesting to note that, although feldspar is present in equal quantities, in all the soils, there is variation in alteration. There is a probable decrease in the weathering of the orthoclase feldspar and may be taken as an advance stage of weathering.

As regards the heavy minerals, ferrugenous material decrease down the slope. The presence of these particles indicate the weathered nature of the soil. The most resistant minerals, zircon and tourmaline are found throughout the sequence. Zircon is increasing while tourmaline and hornblende are decreasing down the slope.

Considering the topographic sites on which they occur, it is probable that weathered materials have been subsequently transported by creep through surface run off and weathering has caused further changes in the soil. The overall picture of the primary minerals in the fine sand fraction shows more or less uniformity in the petrographic composition. This may be taken as an evidence of the uniformity of the parent material at a certain stage of soil formation. This is quite reasonable as relatively small area of the catenary site under investigation.

Minerological make up of the clay fraction

Identification of clay mineral by staining test

A preliminary identification test was done by following the procedure suggested by Richard C. Mielenz (1950). The minerological composition was tested out and the resulted obtained for clay fractions of soil samples in all the three profiles of the toposequence are furnished in Table 10.

Table 10. Minerological make up of the clay fraction (Staining Test)

DIGLIPUR SEQUENCE

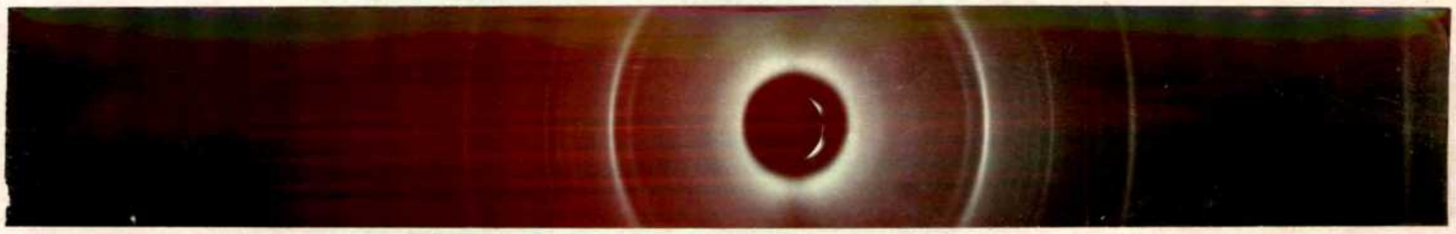
Soil series	Depth (cm.)	Montmorillonite	Ilite	Kaolinite
Diglipur upper series (DI)	0-10.5	Present	Present	Present
	10.5-37	Present	Present	-
Diglipur mid series (DII)	0-15	Present	Present	Present
	15-45	Present	-	Present
Diglipur valley series (DIII)	0-19.5	Present	-	-
	19.5-40	Present	-	-

The staining test revealed the presence of montmorillonite in all the three profiles (DI, DII and DIII). Whereas illite is present in the upper series (DI) and mid series (DII), kaolinite is present in the upper members DI and DII. The observations recorded is in line with the findings of other studies taken up later by X-ray diffraction and differential Thermal Analysis.

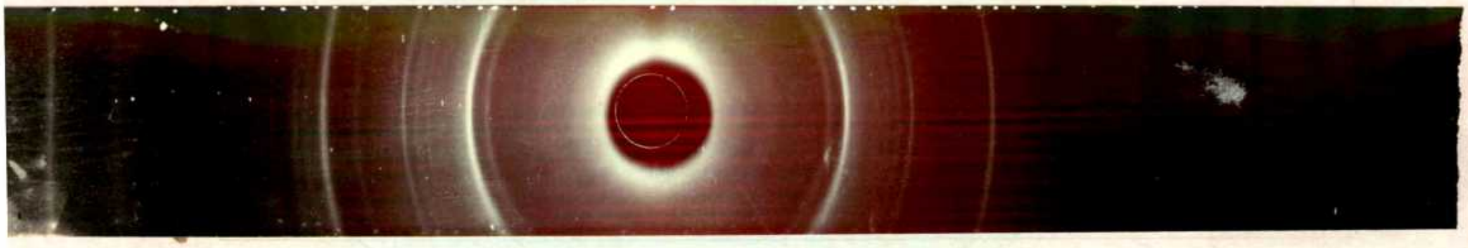
X-ray diffraction Analysis

Clay minerals are the end product of weathering. Clay minerals in the clay fractions of the soils under investigation were identified by X-ray data based upon diffraction photographs. X-ray diffraction patterns of few samples are shown in Plate XI table 11 by positive sign and absence by negative sign. The three clay minerals identified are montmorillonite, illite and kaolinite. Montmorillonite is identified as a major (25-50%) and Illite and Kaolinite as trace (5-10%).

The minerological make up of the samples from three profiles of the sequence indicate their similarity and relationship. The intensity of montmorillonite lines appears to be more with depths and from upper member (DI) to lower valley profile (DIII). The relative intensity of illite and kaolinite lines are weaker in the toposequence from the upper members (DI) to the valley profile (DIII). The presence of montmorillonite in these clay fractions manifests itself in the increase of cation exchange capacities of clay fraction and silica sesquioxide ratios. In the valley soil illite and kaolinite are absent and montmorillonite predominates.



DI DIGLIPUR UPPER SERIES



DII DIGLIPUR_MID SERIES

DIII DIGLIPUR_VALLEY SERIES

PLATE XI X-RAY DIFFRACTION PHOTOGRAPHS OF SOME CLAY SAMPLES - DIGLIPUR SEQUENCE

These observations have support from CEC's and chemical composition of the clay fractions. CEC shows an increasing trend from profile to profile down to slope. Potassium has recorded a decreasing tendency from the upper member DI to the valley member DIII. Whereas magnesium is having an increasing tendency from the upper soil profile (DI) to valley profile (DIII). During the present investigation montmorillonite is dominant in all the profiles with varying degrees of intensities. Presence of illite and kaolinite is noticed under low environment of calcium and magnesium ions as can be seen from data on exchangeable calcium and magnesium.

Table 11. Crystalline components of the clay fraction (X-ray analysis)

DIGLIPUR SEQUENCE

Soil series	Depth (cm)	Montmori-llonite	Illite	Kaolinite
Diglipur upper series (DI)	0-10.5	++++++	+++	+++
	10.5-37	++++++	+++	+++
Diglipur mid series (DII)	0-15	++++++	+++	+++
	15-45	++++++	+++	+++
Diglipur valley series (DIII)	0-19.5	++++++	-	-
	19.5-40	++++++	-	-

+ Relative abundance

- Absence

++++++ Major (25-50%)

+++ Trace (5-10%)

Montmorillonite developed under the peculiar oceanic climatic condition of these islands might be probably unstable.

The petrographic composition of the fine sand fractions show the similarity of parent materials and the dominance of orthoclase feldspar which are under varying degrees of alteration depending upon the topographic situation. Plageioclase feldspars either altered or partially altered are usually associated with montmorillonite. According to Grim (1953) an acid igneous rock containing potassium as well as magnesium under weathering conditions permitting the potash and magnesium to remain in the weathering environment after the breakdown of the parent minerals, will yield illite and montmorillonite as alteration product. If the content of magnesia is low, illite is the only product and if the potash content is low, montmorillonite will be the only product.

Evidences in literature show that there is difference of opinion as to the transformation of montmorillonite to illite and vice versa. Special conditions of high rain fall for about nine months in an year and oceanic environment and parent materials might have influenced formation of montmorillonite as the major clay mineral.

Differential Thermal Analysis

Differential thermal analysis was used for minerological investigation of the clay samples of surface layers of the profile of toposequence. The information obtained from the study of DTA is used to supplement the results obtained by X-ray analysis.

The relative abundance of minerals revealed by the Differential Thermal Curves are furnished in Table 12 and Plate XII.

Table 12. Crystalline components of the clay fraction (Differential thermal analysis)

DIGLIPUR SEQUENCE

Sour series	Depth (cm.)	Montmorillo--nite	Illite	Kaolini--te	Magna-tite
Diglipur upper series(DI)	0-10.5	++++++	-	+++	-
	10.5-37	++++++	-	+++	-
Diglipur mid series (DII)	0-15	++++++	+++	-	-
	15-45	++++++	-	-	-
Diglipur valley series(DIII)	0-19.5	++++++	+++	-	-
	19.5-40	++++++	+++	-	-

\+ Relative abundance

\- Absence

++++++ Major (25-50%)

+++ Trace (5-10%)

The presence of montmorillonite in all the profiles of the toposequence DI, DII and DIII is relatively abundant. Other minerals identified are illite, kaolinite and magnetite. Kaolinite (Trace) is present only in the upper slope member DI. Illite is present in trace only in Diglipur mid series (DI) and Diglipur valley series. The general trend of observation on the distribution of minerals is similar to that of X-ray diffraction studies on the

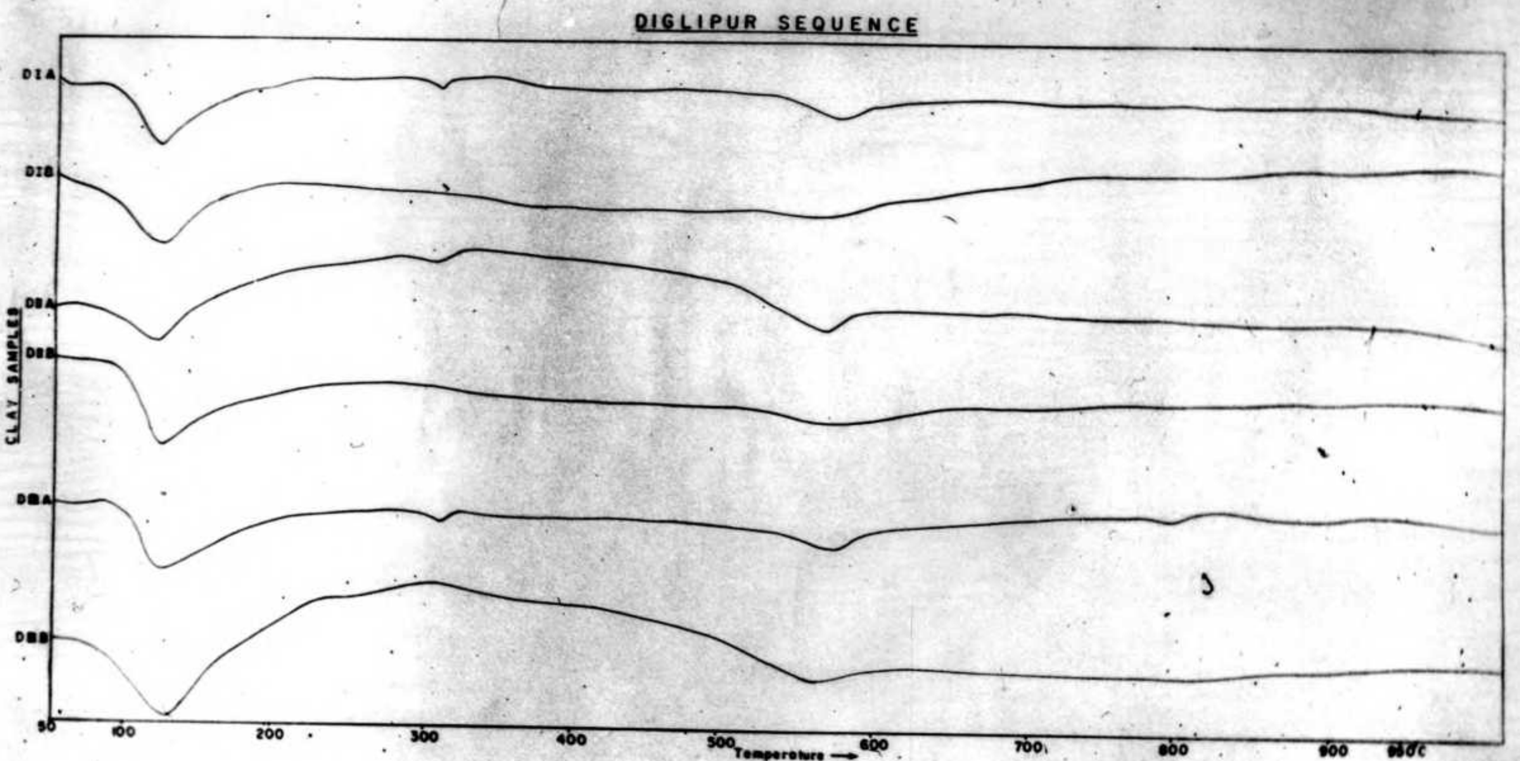


PLATE XVI DIFFERENTIAL THERMAL ANALYSIS CURVES OF SOME CLAY SAMPLES - DIGLIPUR SEQUENCE.
DI DIGLIPUR UPPER SERIES A0-10·5 cm. B10.5 - 37cm
DII DIGLIPUR MID SERIES A0-15 cm B15-45 cm.
DIII DIGLIPUR VALLEY SERIES- A0-19·5 cm. B19·5 - 40cm.

same samples. It is inferred from the DTA curves that kaoline is poorly crystallised as its high temperature exothermic peak is absent. Endothermic DTA peak of kaoline appears to have been submerged with that of illite. Presence of magnatite in trace is also identified. The formation of montmorillonite probably takes place during weathering of ferromagnesium minerals and feldspars of the parent rock are decomposed simultaneously thus releasing ferrous and ferric iron, magnesium, alumina and silica.

B. RANGAT SEQUENCES

1. Morphology of the profile

A comparative study of the morphology of the profiles RI, RII, RIII of Rangat Sequence with that of Diglipur sequence reveals similarity in features as in Diglipur sequence (Plate VII). Change in colour along the slope is gradual, dark reddish brown merging into dark greyish brown through dark yellowish brown and it represents a toposequence from the upper slope member to the valley as in the case of Diglipur sequence. No appreciable difference in colour could be noticed within the profile although there is little change in the chroma. The profiles are designated on the basis of topographic situation and the characteristic features of each profile are described below (Plate VIII).

Morphological description of the Profiles

Rangat upper series (R.I)

Comprises very deep, well drained soils derived from sandstone and shale parent material occurring on steep (25-33%) upper slopes of medium hills. The pedons have dark reddish brown, medium textured A horizon grading to dark reddish gray to light reddish brown, moderately fine textured B horizon. The soils are moderately eroded.

Rangat upper series is a member of fine clayey mixed hyperthermic family of Mollic Hapludalf.

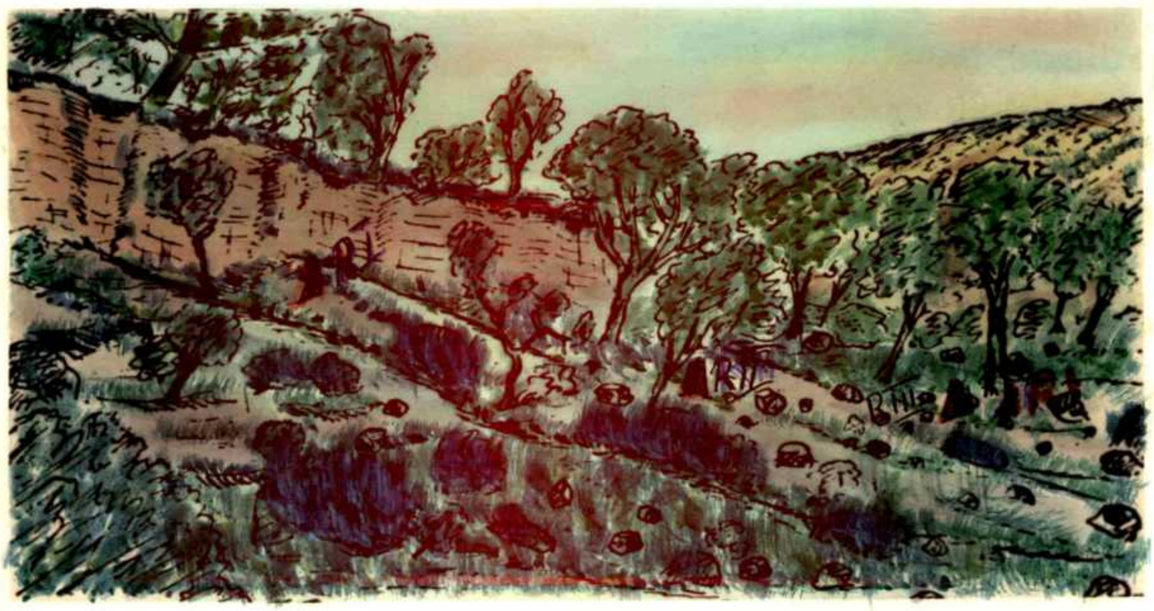


PLATE VII DIAGRAMATIC PRESENTATION OF THE LANDSCAPE AND PROFILE SITES OF RANGAT SEQUENÇE

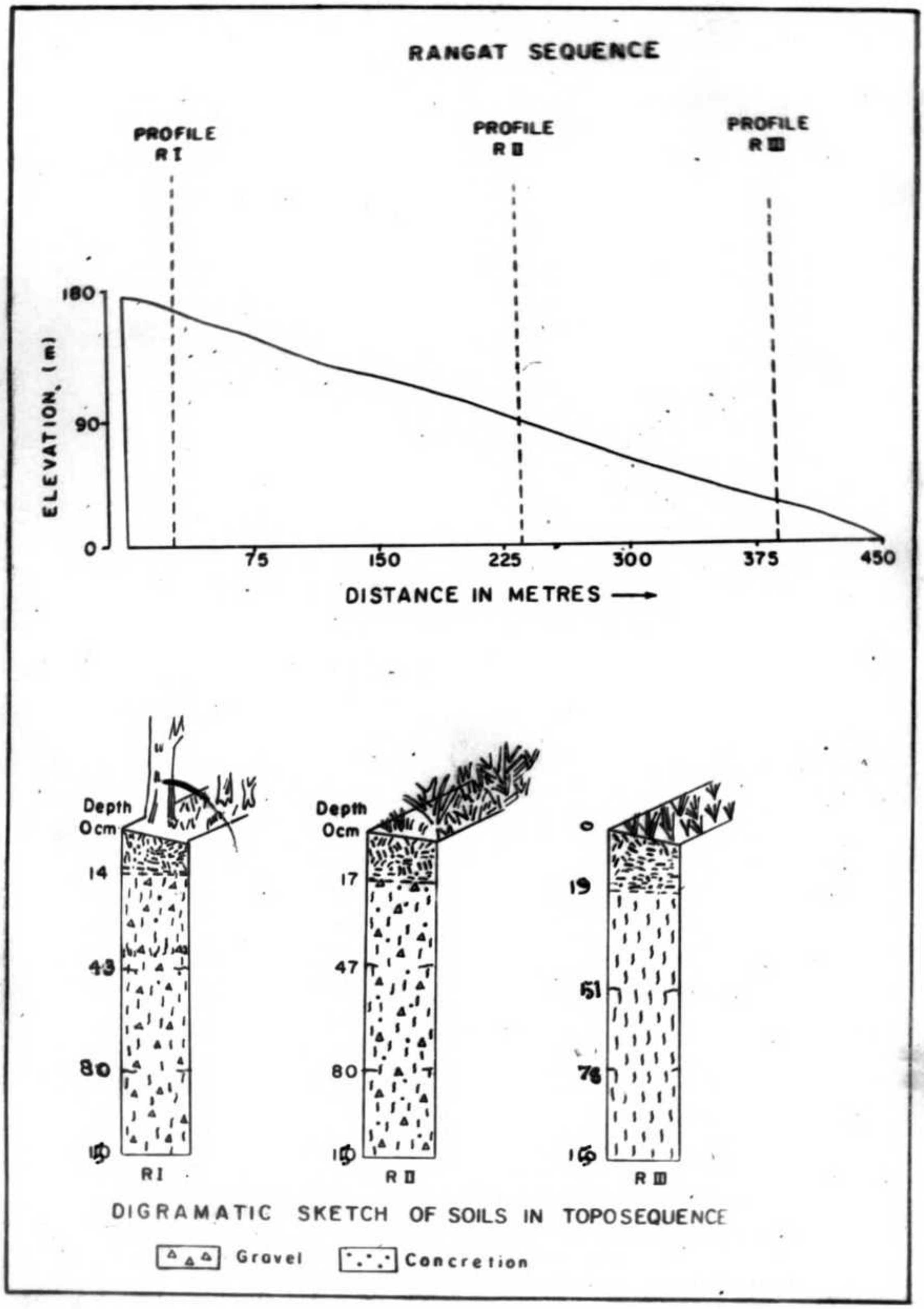


PLATE VIII - DIAGRAMATIC SKETCH OF SOILS IN TOPO-SEOUENCE - RANGAT SEQUENCE

Horizon	Depth (cm)	Description
A1	0-14	Dark reddish brown (5YR3/2 moist) loam; weak, fine, granular, friable, slightly sticky, slightly hard, slightly plastic; abundant fine medium continuous, tubular pores; abundant fine and medium roots; gradually smooth; wavy boundary.
B21t	14-43	Dark reddish gray (5YR4/2 moist); clay loam; distinct, few fine, medium reddish yellow (7.5YR6/6) mottles; moderate, medium, subangular blocky structure; slightly hard friable; very sticky, very plastic; thin patchy clay skin; common, fine, medium roots follow ped faces; common fine and medium pores; clear smooth wavy boundary.
B22t	43-80	Reddish brown (2.5YR5/4 moist) clay loam; fine, few distinct 2.5YR6/2 mottlings; moderate, medium, subangular blocky structure; slightly hard friable sticky, slightly plastic; thin patchy clay skins; few fine roots follow peds faces; common, fine, tubular,

Horizon	Depth (cm)	Description
		discontinuous pores; soft few sandstone parent material present, clear smooth boundary.
C1	80-150	Light reddish brown (2.5YR6/4) few, fine distinct reddish brown (5YR5/3) mottles; sandy clay loam; moderate, medium and coarse breaking to weak, fine and medium, subangular blocky structure; slightly sticky, slightly plastic; few, small ferrugenous concretions; partly weathered fragments of soft sandstone parent material present.

Range in characteristics

Solum depth is very deep. Surface colour ranges from dark reddish brown to reddish brown in hue 5YR with value 3 to 4 and chroma 2 to 3; texture of the fine earth is loam. B horizon ranges from dark reddish gray to light reddish brown in hue 2.5YR to 5YR with value 4 to 6 and chroma 2 to 4. The clay content gradually increases with depth and reaches maximum in B22t horizon.

Drainage and permeability

Well drained; permeability moderate; Run off moderately rapid.

Use and Vegetation

Mostly under mixed deciduous forest.

Distribution and extent

Occur extensively on upper slopes of medium hills in Middle and South Andaman.

Series established and type location

Rangat upper series : 84 km north of Port Blair, 10°18' north latitude and 92°59' east longitude at an elevation of 170 m. M.S.L.

Rangat mid series (R.II)

Comprises very deep, moderately well drained soils derived from sandstone and shale parent materials occurring on strongly sloping (10-15%) mid slope of medium hills. The pedons have dark yellowish brown moderately fine textured A horizon grading to yellowish brown to grayish brown moderately fine to fine textured B horizon. The soils are moderately eroded.

Rangat mid series is a member of fine clayey mixed hyperthermic family of Typic hapludalfs.

Typifying pedon : Rangat mid sandy clay loam (Colours are for dry soils unless otherwise-noted)

Horizon	Depth (cm)	Description
A1	0-17	Dark yellowish brown (10 YR4/4 moist) sandy clay loam; moderate, medium, coarse breaking into fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; abundant fine and

Horizon	Depth (cm)	Description
		medium pores; abundant fine and medium roots; clear wavy boundary.
B1	17-47	Yellowish brown (10YR5/6 moist) clay loam; common, fine, medium brown (10YR5/3) mottles; strong, fine, subangular blocky structure; common, fine and medium roots; common, fine, medium pores; few soft particles of sandstone particles present; clear wavy boundary.
B2t	47-80	Yellowish brown (10YR5/4 moist) clay; strong, medium, blocky; sticky, plastic, firm, hard, continuous clay skins on ped faces; partly weathered soft sandstone materials present; smooth, wavy boundary.
B3	80-150	Grayish brown (2.5Y 5/2 moist), clay, few faint light gray mottling (2.5Y 7/2); strong medium to coarse, angular blocky structure; firm, hard; partly weathered soft sandstone material is present.

Range in characteristics

Solum depth is very deep. Surface soil colour is dark yellowish brown in hue 10YR with value 4 to 5 and chroma 4 to 5;

the texture ranges from sandy clay loam to clay loam. Subsoil colour ranges from yellowish brown to grayish brown in hue 10YR with value 5 and chroma 2 to 6. The clay content gradually increases with depth and reaches maximum to B2t horizon.

Drainage and permeability

Well drained; permeability moderate; Run off is moderately rapid.

Use and Vegetation

Mostly under horticultural crops, and other homestead crops are also cultivated.

Distribution and Extent

Occur extensively on mid-slopes of medium hills in Middle and South Andaman Islands.

Series established and type location

Rangat mid series : 84 km north of Port Blair, 10°18' north latitude and 92°59' east longitude at an altitude of 60 m. M.S.L.

Rangat Valley series (R.III)

Comprises very deep, imperfectly drained soils derived from colluvial and alluvial material occurring on very gently slopping (1-3%) valley land. The pedons have dark grayish brown, moderately fine textured A horizon grading to grayish brown to light olive brown, moderately fine to fine textured B horizon. The soils are moderately eroded.

Rangat valley series is a member of fine clayey mixed hyperthermic family of Typic ochraqualfs.

Typifying pedon : Rangat valley clay loam

(Colours are for dry soils unless otherwise noted).

Horizon	Depth (cm)	Description
Ap	0-19	Dark grayish brown (2.5Y 4/2 moist), clay loam; subangular blocky structure; very hard, very sticky, very plastic; abundant fine, medium pores; vertical and horizontal cracks in the soil; abrupt wavy boundary.
B1	19-51	Gray (10YR5/1 moist) clay; strong medium to coarse angular blocky structure; very hard, very firm, very sticky, very plastic; common fine, medium pores; common fine, medium, roots; vertical and horizontal cracks; clear and wavy boundary.
B21tg	51-78	Olive gray (5Y 5/2 moist) clay; moderate fine blocky structure to massive; firm when moist; thin patchy clay skin on vertical ped faces, few black (2.5Y 2/0) small concretion; few fine pores; diffuse and wavy boundary.

Horizon	Depth (cm)	Description
B22tg	78-150	Light brownish gray (2.5Y 6/2 moist) clay, strong medium, angular blocky; very firm, very sticky, very plastic; few , fine, faint light gray (2.5Y 7/2) mottling; thin continuous clay skins on ped faces.

Range in characteristics

Solum depth is very deep. Surface soil colour is dark grayish brown in hue 2.5Y with value 4 to 5 and chroma 2 to 3; texture clay loam. Subsoil colour ranges from grayish brown to light olive brown in hue 2.5 with value 5 to 6 and chroma 2 to 6. The texture of the fine earth is clay. The clay content gradually increases with depth and reaches maximum in B22tg horizon.

Drainage and permeability

Imperfectly drained; permeability moderately slow to slow; Run off is moderate.

Use and Vegetation

Mostly cultivated for paddy and other field crops.

Distribution and Extent

Occur extensively on valley lands in Middle and South Andaman Islands.

Series established and type location

Rangat valley series : 54 km. north of Port Blair, $10^{o}18'$

north latitude and $92^{o}59'$ east longitude at an elevation of 7 m. M.S.L.

2. Colour of the soils and their clay fraction

Soil colour plays an important role as in the previous series. The soils in the present investigation follow the gradation change down the slope similar to that of Diglipur sequence. The effect of treatments on the colour of the soil and clay is discussed below (Tables 13 and 14). The distribution of organic matter as seen from the Table 17 may not be an indication to show the darker shades are due to the organic matter; oxidation of organic matter with hydrogen peroxide did not show much variation in the colour. When the samples were pre-treated with dilute hydrochloric acid, the oxidation of organic matter by hydrogen peroxide showed little difference in colour.

A change in chroma observed may be attributed to the organic matter and calcium.

Colour in relation to free oxides in the soils

Removal of free oxides from the upper members (R.I) gives rise to reddish grey. Yellowish colour of the soil disappears as a result of removal of free oxides. Colour of the clays are more or less the same as in the corresponding soils and it may be probable that colour of the soils is influenced by the colour of their mechanical fractions particularly the clays as reported earlier by Joshi (195?). As seen from the Tables 13 and 14 the

Table 13. Colour of the soils

RANGAT SEQUENCE

Soil series	Depth (cm)	Field observation	On air dried	On removal $CaCO_3$ and organic matter	On removal of free oxides
Rangat upper series (R.I).	0-14	5YR3/2	5YR4/3	5YR4/2	5YR4/1
	14-43	5YR4/2	5YR5/2	5YR4/2	5YR4/1
	43-80	2.5YR5/4	5YR/5/3	5YR5/3	5YR5/1
	80-150	2.5YR6/4	2.5YR6/2	2.5YR6/3	2.5YR6/0
Rangat mid series (R.II)	0-17	10YR4/4	10YR5/4	10YR5/3	10YR5/2
	17-47	10YR5/6	10YR5/4	10YR5/4	10YR5/2
	47-80	10YR5/4	10YR6/4	10YR5/4	10YR5/2
	80-150	2.5Y5/2	2.5Y6/2	2.5YR5/2	2.5YR5/1
Rangat valley series (R.III)	0-19	2.5Y4/2	2.5Y5/2	10YR5/2	10YR5/1
	19-51	10YR5/1	10YR5/1	10YR5/2	10YR5/1
	51-78	2.5Y5/2	2.5Y5/2	10YR5/3	10YR5/1
	78-150	2.5Y6/2	2.5Y5/2	10YR5/3	10YR5/1

diminishing of yellow and reddish shades of colour indicates that there is some relation between the amount of free oxides and colour of the soils. It appears that free iron in different state of hydration may be the cause of the difference in colour. The results are in agreement with that of Stace (1956) who found in Terrarossa and rendzina soils that the redness of the soil was associated with free iron oxides present in the clay portion

Table 14. Colour of the clay fraction

RANGHAT SEQUENCE

Soil series	Depth (cm)	Original	On removal of free oxide
R.I	0-14	5YR5/3	5YR6/1
	14-43	5YR6/2	5YR5/2
	43-80	5YR5/4	2.5YR5/2
	80-150	5YR6/4	5YR6/2
R.II	0-17	10YR5/4	10YR5/3
	17-47	10YR5/6	10YR5/4
	47-80	10YR5/4	10YR5/2
	80-150	2.5YR5/4	2.5YR5/2
R.III	0-19	10YR5/3	10YR5/2
	19-51	10YR5/4	10YR5/2
	51-78	10YR5/3	10YR5/1
	78-150	10YR5/3	10YR5/2

which is more than non-clay portion that has the greater influence on colour than with the coarser fraction. Similar were the observations of Kelly et al. and Joshi (1945), Yellowish colour of the soil may be due to iron in hydrated form possibly limonite which gives the soil yellowish colour.

Mechanical composition of the soils

Mechanical composition of the soils show similar gradation in toposequence as observed in Diglipur sequence (D.1). Moisture, pH and clay content increase down the slope. Presence of gravel is found in both the soils of upper slope members. Presence of gravel in the upland soils is recorded by Radwanski and Oliver (1959).

Soil reaction

The pH value indicates that higher slope members are more acidic than the lower slope members. The acidic nature is characterised as advanced degree of leaching. There is gradational increase in the soil pH with the decrease in the topographic situation. The reason for such increase is obvious and explained previously. The increasing pH may be related to expanding lattice type of minerals and relatively higher Cation exchange capacity.

Mechanical constituents of the soil

Mechanical constituents of the soil (Table 15) present characteristic features both within the profiles as well as between the profiles. The present gradational change in the composition of

Table 15. Analytical data: Mechanical constituents of soils (Expressed in percentage on oven dry basis)

RANGAT SEQUENCE

Geomorphic Unit.	Soil Series	Horizon	Depth (cm.)	PH 1:2.5	Organic Carbon	Gravel	Coarse Sand 0.2-0.2mm	Fine sand 0.2-0.2mm	Silt .02-.002 mm.	Clay (< 0.002) mm.
Medium hill upper slope	R I	A1	0-14	6.00	0.74	1.5	10.22	32.58	31.0	26.2
		B21t	14-43	5.9	0.52	10.25	8.34	28.92	25.74	37.0
		B22t	43-80	5.8	0.21	12.00	6.25	30.55	24.1	39.1
		C1	80-150	5.9	0.17	25.50	5.98	41.50	22.1	30.42
Medium hill	R II	A1	0-17	5.8	0.61	2.00	14.82	37.08	23.1	25.0
Mid-slope		B21t	17-47	6.1	0.42	15.62	13.3	23.7	22.0	41.0
		B22t	47-80	6.2	0.31	16.35	14.6	13.2	19.1	53.1
		B3t	80-150	6.0	0.12	28.15	14.14	17.85	17.81	50.2
Valley	R III	Ap	0-19	6.5	0.55	-	3.68	21.22	38.4	36.7
		B21t	19-51	6.2	0.38	-	0.78	15.12	34.4	49.7
		B22t	51-78	6.0	0.22	-	0.72	8.18	39.4	51.7
		B23t	78-150	6.5	0.12	-	0.36	8.54	37.4	53.7

soil along the slope and is similar to a great extent of the soil sequence described earlier (Diglipur Sequence). Clay content of the Surface Soil increases from the Upper member (R.I) to the lower member (R.III). Clay content in all the soils increases with the depth within the profile. This marked change with the depth of the clay content is better explained if their topographic situations, feature and structure are considered.

There is regular decrease in Silt content down the profiles of the upper slope members (R.I and R.II) whereas the distribution is more or less similar within the profile of the lower member (R.III) which is poorly drained.

Upper slope members are considerably higher in the coarse sand, increasing down the profile, whereas lower slope member (R. III) is practically devoid of coarse sand. The data also reveal the active migration of the finer particles down the slope and represent the gradation of the mechanical separates related largely to the topographic situation. In general the mechanical composition corroborate the results obtained earlier (Diglipur Sequence).

Organic Carbon and Nitrogen

The distribution of organic Carbon content (Table 16) of the surface soils is appreciable and increases down the slope. The decrease of organic matter down the profile is observed in all the profiles of the sequence. The highest Nitrogen content is observed in Rangat mid-series (R.II). The pattern of distribution within the profile is more or less similar to that of carbon.

Table 16. C/N ratio of the soil
(Expressed in percentage on oven dry basis)

RANGAT SEQUENCE

Soil series	Depth (cm)	Organic carbon	Organic nitrogen	C/N Ratio
R.I	0-14	0.74	0.061	12.1
	14-43	0.52	0.049	10.5
	43-80	0.21	0.021	9.9
	80-150	0.17	0.018	9.4
R.II	0-17	0.61	0.069	10.6
	17-47	0.42	0.051	10.1
	47-80	0.31	0.022	9.4
	80-150	0.12	0.019	8.6
R.III	0-19	0.55	0.053	10.2
	19-51	0.38	0.038	9.9
	51-78	0.22	0.023	9.4
	78-150	0.12	0.013	8.8

Carbon-Nitrogen ratio

The C/N ratio do not show much variation in the surface soils of the sequence. The C/N ratios for the soils in toposequence are higher in the surface than down the profile. This increase may be accounted for by the seasonal leaf fall and other additions of highly cellulosic material of the vegetation. It may also be probable that the change in the environment down the profile as a result of moisture conditions and base supply lead to the decomposition of organic matter, thereby decreasing the C/N ratio. The trend of result is also in agreement with the observations of Hollsworth et al. (1952), Muir et al. (1957) and Agarwal et al. (1957).

Cation exchange capacity of soils

Cation exchange capacity (Table 17) of the soils show a similar gradation as that of topography. C.E.C. of different soil profiles show an increase from the upper member R.I to lower member R.III. The relatively high cation exchange capacity of the soils is an indication to the nature of the clay. This further confirmed by the chemical composition of the clays and mineralogical studies. In the well drained soils of higher slope members there is increase in CEC down the profile and this increase is approximately in proportion with the clay content of the soils. In poorly drained soils of lower members, CEC is more or less uniform with the uniform distribution of clay.

Exchangeable Cations

The variation in the exchangeable cations presents a characteristic pattern in soil sequence. Calcium predominates in the exchange complex in all the horizons of the profiles. The percentage of exchangeable calcium increases down the slope. Exchangeable calcium increases down the profiles of upper slope members R.I and R.II, but is more or less uniformly distributed in the lower slope profiles. This is probably due to the effect

Table 17. Cation Exchange Capacity and Exchangable Cations of the soil
(Expressed in m.e. Percent on oven dry basis)
RANGAT SEQUENCE

Soil Series	Depth (cm)	CEC m.e.% 100g.	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Total	Base Saturation (Percent)
Rangat	0-14	18.5	9.56	5.32	0.28	0.44	15.6	84.32
upper	14-43	26.7	14.27	7.77	0.34	0.92	23.3	87.26
series	43.80	27.18	14.64	8.67	0.32	0.81	24.4	87.76
R I	80-150	20.37	10.00	6.37	0.19	0.44	17.0	83.45
Rangat	0-17	17.5	8.05	5.26	0.26	0.61	14.18	84.57
mid	17-47	28.7	16.44	8.04	0.37	0.20	25.1	87.45
series	47-80	37.8	20.72	11.19	0.48	0.59	33.61	88.9
R II	80-150	35,2	20.35	11.13	0.33	0.31	32.12	91.25
Rangat	0-19	25.69	12.99	7.68	0.41	0.43	22.01	85.67
Valley	19.51	34.70	20.49	10.62	0.61	0.08	31.80	91.64
Series	51-78	36.01	21.23	11.19	0.40	0.09	32.91	91.39
R III	78-150	37,00	21.32	11.91	0.38	0.28	33.91	91.64

of drainage.

Exchangeable magnesium also shows increase down the slope as also down the profiles of the sequence. There is gradual increase in the exchangeable Sodium down the slope as well as d the profile. The percentage of Sodium in the exchange complex does not show much variation within the profile as well as betw the profile.

Exchangeable Potassium is only a very small part of the exchangeable cations and follows the toposequence as that of exchangeable Sodium.

Chemical Composition of the Clay fraction

Chemical composition of the clay fractions (Table 18) of the soils of Rangat Sequence is in toposequence as it has been found in the case of Diglipur sequence. Variation of the const: tuents down the slope is well marked, showing either decrease o: increase. The upper slope members are more sesquioxidic than t: lower ones. Each constituent is discussed below :

Silica

The Silica contents of clay fractions of the surface soils increase down the slope as the drainage becomes poorer. Silica constitutes a greater portion of the clay fraction. The drainag appears to be principal cause of loss of Silica along the slope.

Sesquioxides

There is increase in Silica content with corresponding

Table 18. Chemical Constituents of Clay Fraction. Rangat Sequence.

(Expressed as percentage on ignited basis)

Name of Series	Depth Cms.	Moisture	Loss on ignition	S_iO_2	R_2O_3	Al_2O_3	Fe_2O_3	$Ti\ O_2$	Mn O	Ca O	Mg O	K_2O	$\frac{S_iO_2}{R_2O_3}$
Rangat Upper series (R.I)	0-14	8.1	12.89	46.00	35.1	22.71	12.08	0.31	0.21	1.51	2.33	2.60	2.59
	14-43	7.50	11.81	46.10	35.50	22.31	12.98	0.21	0.18	1.62	2.35	2.56	2.55
	43-80	8.91	11.41	46.41	35.90	23.10	12.38	0.42	0.11	1.91	2.41	2.50	2.54
	80-150	10.21	11.46	46.51	35.60	23.70	11.39	0.51	0.14	2.10	2.41	3.10	2.55
Rangat Mid Series (R.II)	0-17	8.50	11.81	47.21	34.65	23.41	11.03	0.21	0.19	1.81	2.67	2.61	2.63
	17-47	8.61	11.80	46.41	34.96	22.67	12.02	0.28	0.25	1.71	2.79	2.40	2.59
	47-80	10.01	11.85	45.91	35.50	23.71	11.48	0.31	0.29	1.61	2.81	2.32	2.52
	80-150	10.30	9.00	48.60	36.12	23.10	11.91	0.11	0.11	2.17	2.70	2.21	2.60
Rangat Valley Series (R.III)	0-19	8.81	11.10	47.51	35.31	22.71	12.48	0.12	0.11	2.01	2.82	2.01	2.68
	19-51	10.40	10.01	48.81	34.19	23.51	10.43	0.25	0.09	2.21	2.91	2.03	2.75
	51-78	10.45	10.30	47.71	34.81	22.61	12.12	0.08	0.08	2.41	3.11	2.71	2.66
	78-150	10.21	11.20	47.01	34.61	21.91	11.79	0.91	0.09	2.31	3.00	2.85	2.75

decrease in the sesquioxides as the drainage becomes poorer. Clays of upper slopes are more sesquioxidic than the others. Thus, it appears that better drainage is the principal cause of the greater loss of silica from the clay complex with the corresponding increase in the sesquioxides. There is marked increase in sesquioxide down the profile in the upper slope members. This is due to the translocation of iron rather than alumina.

Content of iron and alumina follow toposequence in which soils occur. The enrichment of clay in alumina in the well drained soils is gradual, increasing with depth. The clays of the upper slope members R.I and R.II are relatively richer in alumina than those of the lower ones. The variation in alumina in each profile is not appreciable. Iron as compared to alumina is more variable in the freely drained soils and present a characteristic gradation of the drainage conditions.

The Silica sesquioxide ratios which are above two in all the cases shows that perhaps kaoline is not the dominant clay mineral. Mineralogical studies also confirm that the major clay mineral is montmorillonite.

Titanium

Titanium contents of the clay fractions vary in the surface layers from the upper member (R.I) to lower member (R.III). The distribution resembles the earlier discussed Diglipur sequence.

Manganese

Manganese in clay fractions of this sequence resembles that of Diglipur sequence. The distribution of manganese show a decreasing tendency down the slope. Low contents of manganese in the mid slope and valley profiles may also be due to cultivation which encourages the mobility of manganese.

Calcium and Magnesium

The distribution of Calcium in the profile follow toposequence, increasing down the slope. The content of Calcium in the upper slope member (R.I) is the lowest which gradually increase down the slope R.II and R.III. The behaviour of Calcium in the profile is more or less similar to that of Diglipur sequence described earlier.

Magnesium follows the similar pattern of gradation as that of Calcium. Distribution within the profile shows an increasing tendency with depth. As compared to Calcium, Magnesium contents in all the soils of the sequence show higher values.

Potassium

Distribution of potassium in soils follow the toposequence. Slight decrease in the potassium status down the slopes indicates that it is being gradually leached out. The soils of the sequence contain potassic mineral and it is probable there might be direct transformation of feldspar into Illite and than Kaolinite as suggested by Stephen (1952). Presence of Illite and Kaolinite is observed in lesser quantity during the minerological studies.

Cation Exchange capacity of the clay fractions

Cation exchange capacities of the clay fractions (Table 19) shows a gradation in relation to toposequence on which soils occur and resembles closely the observation of Diglipur Sequence described earlier. The Cation exchange capacity increases gradually down the slope from the Upper member R.I to the lower member R.III.

Table 19. Cation exchange capacity of the clay fractions.
(Expressed as m.e. per 100 gm of oven dry clay)

RANGAT SEQUENCE

Soil series	Depth (cm)	Cation exchange capacity
Rangat upper series (R.I)	0-14	65.24
	14-43	65.60
	43-80	66.10
	80-150	66.50
Rangat Mid series (R.II)	0-17	67.12
	17-47	68.50
	47-80	68.82
	80-150	68.50
Rangat valley series (R.III)	0-19	69.40
	19-51	69.52
	51-78	69.92
	78-150	70.51

The cation exchange capacity within each profile shows slight increase down the profile. But the difference between the minimum and maximum of CEC óf the individual profile is not so marked as to indicate the change in the type of mineral. The increase in CEC indicates the montmorillonitic type of clay mineral. The effect of drainage is clearly evident on the CEC of the clays. More well drained is the soil, less cation exchange capacity and vice versa.

Primary minerals of the fine sand fraction

The distribution of primary minerals in the fine sand fraction is presented in Tables 20 and 21. As in the case of Diglipur sequence light separates constitute major portionof the fine sand. The light minerals that form most of the fine fractions indicate that the present soils were formed on pre-weathered material and of the same parent material. Some of the grains

Table 20. Distribution of light and heavy mineral in fine sand fraction (Rangat Sequence)

(Expressed in percentage)

Soil series	Depth	Light fraction	Heavy fraction
Rangat type series (R.I)	0-14	98.4	1.6
	14-43	94.1	5.9
Rangat mid series (R.II)	0-17	98.2	1.8
	17-43	93.9	6.1
Rangat Valley series (R.III)	0-19	95.6	4.4
	19-51	98.5	1.5

Table 21. Mineral composition of the Fine Sand fractions (Expressed in mutual percentage)

RANGAT SEQUENCE

Name of soil series	Depth in (cms)	Light minerals						Heavy minerals									
		Q	OF	PF	M	MM	BM	C	O	Z	T	H	K	S	A	Ap	G
Ranghat upper series(R.I)	0-14	54	36.2	3.8	2	4		1	34.2	28.2	15.1	11.2	1.2	2.0	1	4.1	2
	14-43	51	41.4	2.5	1	5			41.1	29.6	14.9	10.9	1.5				
Rangat Mid series(R.II)	0-17	47	47.0	2.5		3.5			36	36.6	5.6	10.2	1.0	1.3	2.0	2.1	5.2
	17-47	50	45.4			4.6			41	27.0	7.9	12.6	1.6	1.8		1.0	7.1
Rangat Valley series(R.III)	0-19	48	48.9	3.9					35.2	40.1	6.4	7.0	5.2	1		5.1	
	19-51	53	41.7	3.8	1.5				32.2	50.2	3.8	5.7	4.1	2		7.2	0.5

Reference

Q. Quartz, OF. Orthoclase Feldspar, PF. Plagiociase Feldspar, M. Microcline, NM. Muscovite mica,

BM. Biotite, C. Coated, O. Opaque, Z. Zircon, T. Tounmaline, H. Honblende, K. Kynite,

S. Sillimanite, A. Anatase, Ap. Apatite, G. Garnet.

of the fine sand fractions are coated and could not get cleared in spite of repeated treatments with hydrochloric acid for the removal of free oxides. Under the petrographic microscope, it was observed that these iron nodules are the concretions formed over fine grains of quartz, zircon as nucleus. It may be inferred that it is due to the increased degree of weathered nature of the soils under investigation.

In the light fraction, quartz and orthoclass feldspar which quite resistant to weathering constitute major portion whereas in the heavy fraction resistant minerals are zircon and tourmaline. The presence of resistant minerals in the light as well as heavy fractions may be considered as an indication of advanced stage of weathering. Petrographically, different soils do not differ much from one another.

Light minerals

Quartz is abundance in light fractions. They are angular with sharp edges in the upper members R.I and R.II mostly smooth and rounded in the lower member R.III indicating soil creap from upper members of the sequence. D.II in the middle of the sequence indicate the transitional stage from D.I (upper member) to D.III (lower member).

Feldspar

The other light minerals found are orthoclass feldspar, plageoclase feldspar and mica. The upper slope member contains orthoclase completely altered and hazy with altered products.

The alteration of orthoclase feldspar decreases down the profile.

Heavy minerals

More than 50 per cent of the grains are iron stained.

Iron ore

It is mostly rounded grains. A few grains which are light reddish or yellowish in colour in reflected light are probably goethite and limonite. They are relatively more in higher slops than in lower members.

Zircon

They are of various forms. Some are smooth and rounded in shape. The transformation of pyramidal shape to rounded ones suggest that they are in the advanced stage of weathering. Coloured and often rounded zircons characterise the tertiary sediments. Zircon is higher in the lower slope member (R.III) than in the upper ones R.I. and R.II. This might have been transported from higher reaches.

Tourmaline

Tourmaline is another resistant mineral present throughout the sequence. It is relatively higher in the upper slope member than in the lower ones.

Hornblende

Hornblende decreases down the slope from R.I to R.III. They are dark green 'Platy' flake shaped minerals. The distribution in general is like that of Diglipur Sequence. The parent material which is sedimentary in nature has undergone series of weathering cycles before being deposited at the present site. In the present cycle, they are further influenced by the topographic features, that fall into three main categories viz., those formed by tectonic processes, those formed by erosion and those formed by deposition. It is, therefore, probable that the parent material appears to be of uniform character and is quite expected as the Rangat sequence under investigation exists within a limited distance.

Minerological make up of the clay fraction

1. Identification of clay mineral by staining test

Clay minerals of the clay fractions in three profiles of the toposequence R.I, R.II and R.III were tested by staining process for the preliminary identification of the clay minerals. The results obtained are furnished in Table 22.

Montmorillonite is present in all the clay samples of three profiles in the Rangat toposequence. Illite is present in the three profiles, whereas Kaolinite is found in upper series (R.I) and valley series (R.III). The general trend of observation is similar to that of the findings recorded by X-ray diffraction and differential thermal analysis of the clay fraction done later.

2. X-ray Diffraction Analysis

The clay fractions of surface and sub-surface soils were analysed for the minerological composition by X-ray diffraction technique. X-ray diffraction pattern of some samples are shown in Plate XIII. The clay minerals present in three profiles of the toposequence of the site under investigation reveal close relationship of R.I, R.II and R.III as described in the case of Diglipur sequence. Distribution of different clay minerals and their relative abundance in different soils of the sequence

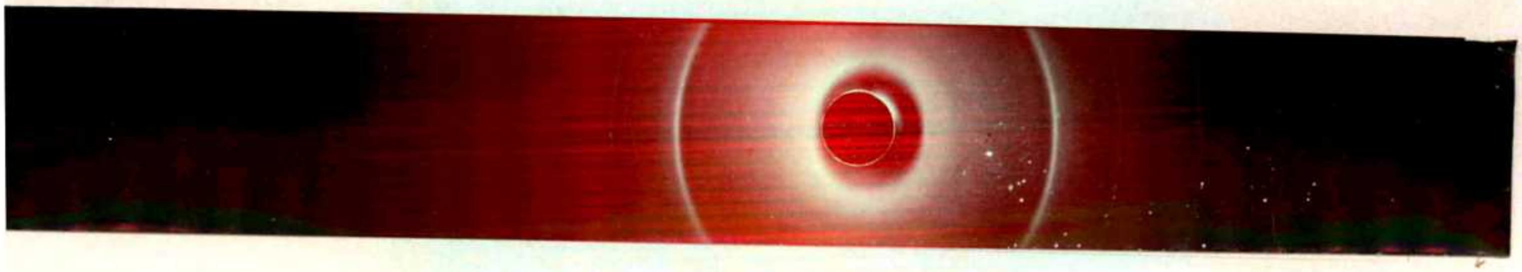
Table 22. Minerological make up of the clay fraction (Staining Test)

RANGAT SEQUENCE

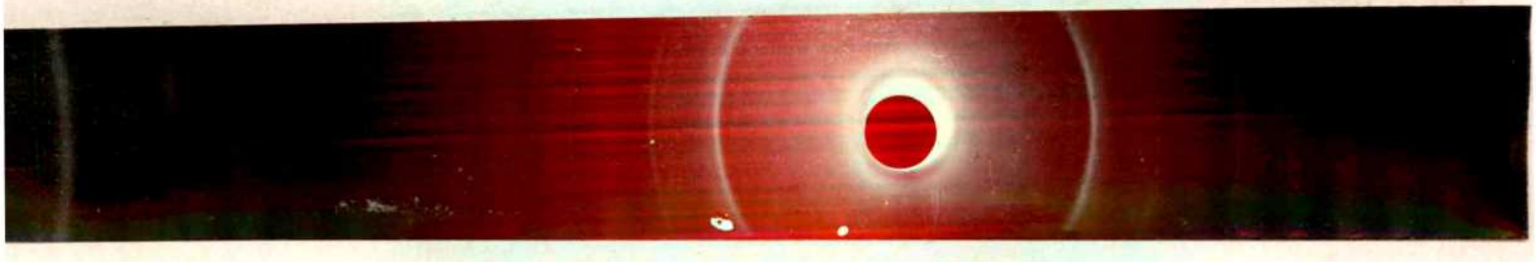
Soil series	Depth (cm)	Montmorillonite	Illite	Kaolinite
Rangat upper series (R.I)	0-14	Present	Present	Present
	14-43	Present	-	-
Rangat mid series (R.II)	0-17	Present	Present	-
	17-47	Present	-	-
Rangat valley series (R.III)	0-19	Present	Present	-
	19-51	Present	Present	Present

is presented in Table 23. The table presents a slight deviation in the distribution of illite (trace) and kaolinite (Trace) in the profiles from R.I to R.III. Illite (Trace) is found throughout the profile in surface layers. It is probable that this may be

RI RANGAT UPPER SERIES



RII RANGAT MID SERIES



RIII RANGAT VALLEY SERIES

PLATE XIII X-RAY DIFFRACTION PHOTOGRAPHS OF SOME CLAY SAMPLES OF RANGAT SERIES due to surface creep from upon horizons, not caused by <u>in situ</u> formation coupled with environmental factors.

Table 23. Crystalline components of the clay fraction (X-ray analysis)

RANGAT SEQUENCE

Soil series	Depth (cm)	Montmorillonite	Illite	Kaolinite
Rangat upper series (R.I)	0-14	++++++	+++	++
	14-43	++++++	+++	++
Rangat mid series (R.II)	0-17	++++++	+++	-
	17-47	++++++	+++	-
Rangat valley series (R.III)	0-19	++++++	+++	-
	19-51	++++++	+++	+++

+ Relative abundance — ++++++ Major; +++ Trace (5-10%); ++ Small amount (5%)

- ABSENCE

The presence of kaolinite (small amount) is observed in the upper member (R.I) which is in tune with the observation made on the minerological composition under different drainage conditions due to topographic feature by a number of workers (Hallsworth <u>et al.</u> 1952; Ferguson, 1954; Mitchell, 1955; Muir <u>et al.</u>, 1957; Mc Aleese & Mitchel, 1958). The absence of kaolinite in the mid slope soil (R.II) and the presence of the mineral (Trace) in Valley profile may be due to localised factor of deposition from elsewhere on the upper site caused by erosion through surface run-off.

3. Differential Thermal Analysis

Differential Thermal Analysis of the clay samples of Rangat sequence under investigation was done to identify the minerological make up of the clay fraction. The Differential Thermal Curves obtained for the clay samples of the soil profiles are furnished in Plate XIV. The distribution of different clay minerals and their relative abundance in soils of the toposequence as judged from the DTA curves is given in Table 24.

Table 24. Crystalline components of the clay fraction. (Differential thermal analysis)

RANGAT SEQUENCE

Soil series	Depth (cm)	Montmorillonite	Illite	Kaolinite
Rangat upper series (R.I)	0-14	++++++	+++	-
	14-43	++++++	+++	+++
Rangat mid series (R.II)	0-17	++++++	+++	-
	17-47	++++++	+++	-
Rangat Valley Series(R.III)	0-19	++++++	+++	-
	19-51	++++++	+++	-

\+ Relative abundance ++++++ Major (25-50%)

\- Absence +++ Trace (5-10%)

Montmorillonite is found to be of relatively major occurrence in these soils. Illite is in trace in all the soils. Kaolinite is present in trace only in upper member of the soils R.I. The general trend of observation is similar to that of earlier findings in X-ray analysis. DTA curves for upper member is moderate in size and too assymatric at 130°C and very shallow trough indicates the presence of montmorillonite and illite. The supporting evidence discussed in the portion of X-ray analysis for different soil is the same for these soils.

Kaolinite is in a poorly crystallised form and the endothermic DTA peak of kaolinite appears to have been submerged with that of illite. Kaolinite in trace is present in the upper member (R.I) of the sequence, while kaolinite (Trace) is observed only in the upper member (R.I).

C. NICOBAR SEQUENCE

1. Morphology of the profiles

The study of different profiles N.I, N.II and N.III of the Nicobar Sequence, reveals considerable similarity with that of Diglipur Sequence and Rangat Sequence described earlier (Plate IX). Change in colour along the slope from upper member (N.I) to the lower member N.III is gradual. It represents a complete topographic sequence from the upper reaches to valley profiles. No appreciable change in colour could be noticed within the profile although there was slight change in the chroma. The gradation of colour was similar as recorded earlier. The profiles are designated on the basis of topographic situation and characteristic features of each profiles are described below (Plate X).

Morphological description of the profiles

Nicobar Upper series (N.I)

Comprises very deep, well drained soils derived from sandstone and shale parent material occurring on steep (25-33%) upper slopes of medium hills. The pedons have dark reddish brown, medium textured A horizon grading to light reddish brown to brown, moderately fine textured B horizon. The soils are moderately eroded.

Nicobar upper series is a member of fine loamy mixed hyper thermic family of Typic Paleudalfs.

Typifying pedon: Nicobar upper clay loam

(Colours are for dry soil unless otherwise noted).

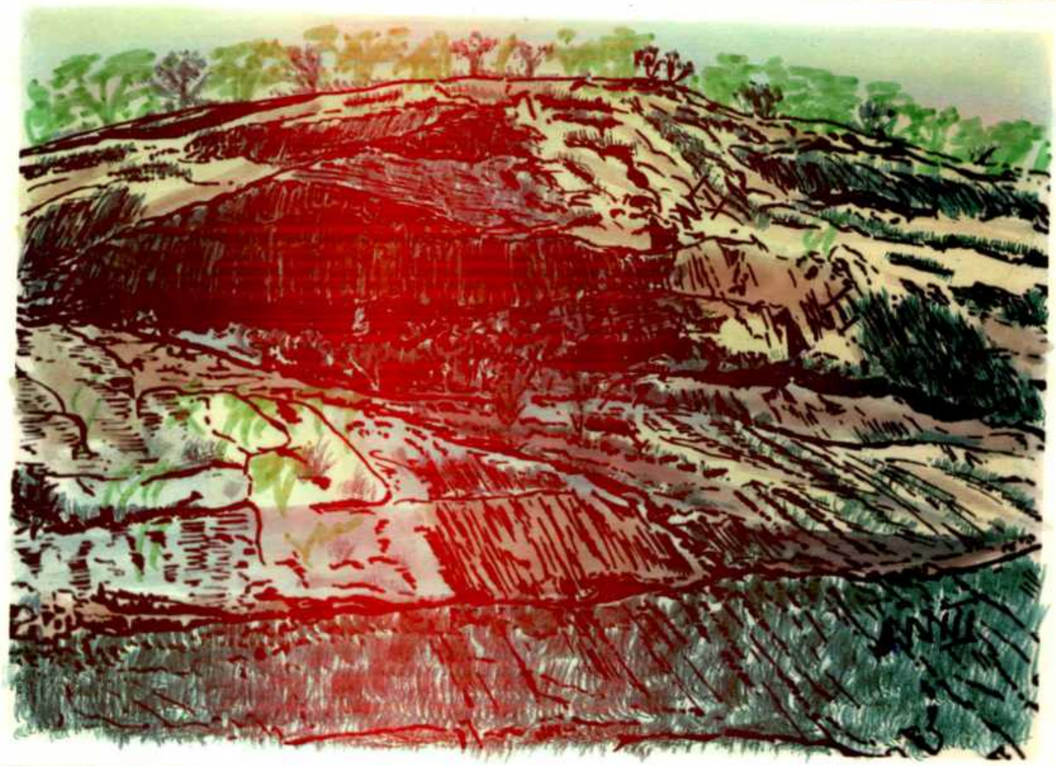


PLATE IX- DIAGRAMATIC PRESENTATION OF THE LANDSCAPE AND PROFILE SITES OF NICOBAR SEQUENCE

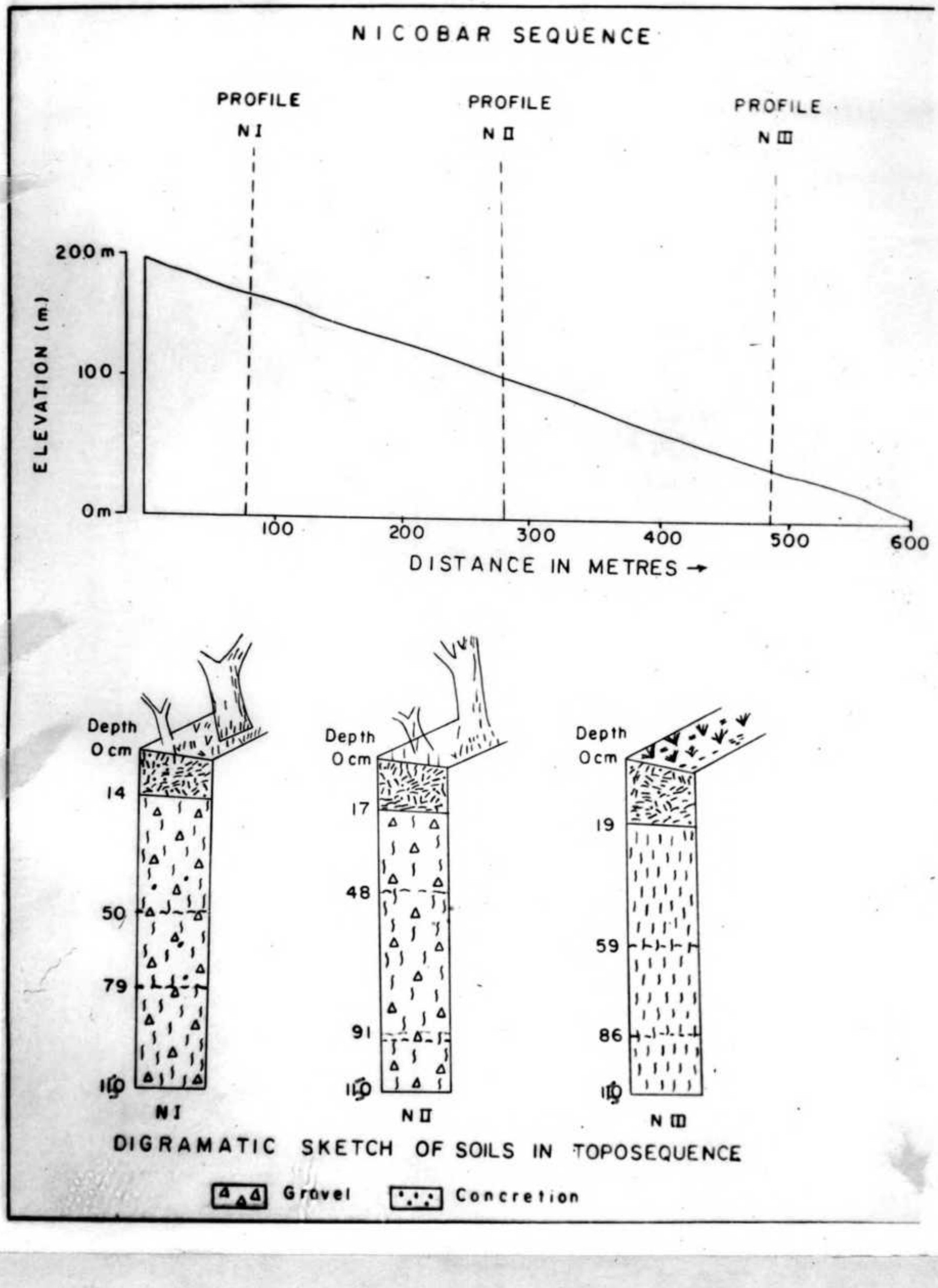


PLATE X - DIAGRAMATIC SKETCH OF SOILS IN TOPO-SEQUENCE - NICOBAR SEQUENCE

Horizon	Depth (cm)	Description
A1	0-14	Reddish brown (5YR 4/3 moist) loam; weak, fine granular; friable; slightly sticky, slightly plastic; abundant fine, medium, few, coarse roots;many few, medium pores, white ant and earth worms present, gradual smooth boundary.
B21t	14-50	Light reddish brown (5YR6/3 moist) silty clay loam; moderate, medium, subangular blocky; slightly hard, friable, very sticky and very plastic; few, fine distinct light brown (7.5YR6/4 mottling; thin patchy clay film on ped faces; frequent, fine roots, common, fine and medium, continuous pores; wavy boundary.
B22t	50-79	Yellowish red (5YR5/6 moist), silty clay loam, moderate, medium, subangular blocky; slightly hard, friable, sticky and plastic; few, fine, medium, distinct strong brown 7.5YR5/6 mottlings; thin patchy clay films on ped faces; few fine pores; few soft sandstone fragments present, smooth wavy boundary.

Horizon	Depth (cm)	Description
B3	79-150	Light raddish brown (5YR6/5 moist) silty clay loam; moderate, medium, subangular blocky structure; slightly hard, slightly sticky and plastic; few distinct medium 7.5YR7/6 reddish yellow mottles; partly weathered soft sandstone and shale particles XX present in the profile.

Range in characteristics

Solum depth is very deep and more than 150 cm. Surface colour ranges from reddish brown to dark reddish brown in hue 5YR with value 4 to 5 chroma 3 to 4; texture is clay loam, B horizon colour ranges from light reddish brown to pinkish gray in hue 5YR with value 4 to 5 and chroma 2 to 3. The clay content gradually increases with depth and reaches maximum in B22t horizon.

Drainage and permeability

Moderately well drained; permeability moderate; Run off moderately rapid.

Use and Vegetation

Mostly under mixed deciduous forest.

Distribution and Extent

Occur extensively on upper slopes of medium hills in Great Nicobar Island.

Series established and type location

Nicobar upper series : 380 km. South of Port Blair, $6^{o}58'$ north latitude and $93^{o}54'$ east longitude at an attitude of 175 m. M. S. L.

Nicobar mid series (N.II)

Comprises very deep, moderately well drained soils derived from sandstone and shale parent materials occurring on strongly sloping (10-15%) mid slope of medium hills. The pedons have dark yellowish brown, moderately fine textured A horizon grading to brownish yellow moderately fine to fine texture B horizon. The soils are moderately eroded.

Nicobar mid series is a member of fine loamy mixed hyperthermic family of Typic Hapludalfs.

Typifying pedon: Nicobar mid clay loam.
(Colours are for dry soil unless otherwise noted).

Horizon	Depth (cm)	Description
A1	0-17	Dark yellowish brown (10YR3/4 moist) silty clay loam; medium, moderate, granular, slightly plastic, slightly sticky, slightly firm; slightly hard; slightly abundant fine; medium fine pores; abundant fine, medium roots; common, fine yellowish brown (10 YR5/8) mottles; thin patchy clay film on ped faces; clear, smooth boundary.

Horizon	Depth (cm)	Description
B21t	17-48	Yellowish brown (10YR 5/4 moist) silty clay loam, moderate medium subangular blocky; slightly hard, slightly firm; very sticky; very plastic; common and medium roots; common fine, medium pores; thin patchy clay film on ped face; clear wavy boundary.
B22t	48-91	Brown (7.5YR 5/4 moist) clay loam; moderate, medium, subangular blocky; slightly sticky, slightly plastic; few fine pores; few, fine medium roots; thin patchy clay film ped faces; fragments of soft sandstone present, clear wavy boundary.
B3	91-150	Brownish yellow (10YR 6/6) silty clay loam; moderate, medium, subangular blocky; slightly sticky, slightly plastic, common, fine yellowish brown (10 YR 5/6) mottles, few, fine pores; partly weathered soft parent material present.

Range in characteristics

Solum depth is very deep. Surface soil colour is dark yellowish brown in hue 10YR with value 3 to 4 and chroma 4 to 5; texture is clay loam. Subs il colour ranges from light yellowish brown to Brownish yellow in hue 10YR with value 5 to 6 and chroma 4 to 6. The clay content gradually increases with depth and reaches maximum in B22t horizon.

Drainage and permeability

Well drained; permeability moderate; Run off is moderately rapid.

Use and Vegetation

Mostly under mixed deciduous forest vegetation.

Distribution and Extent :

Occur extensively on mid slopes of medium hills in Great Nicobar Island.

Series established and type location

Nicobar mid slope : 380 km south of Port Blair, $6^{0}58'$ north latitude and $93^{0}54'$ east longitude at an elevation of 90 m. M.S.L.

Nicobar Valley series (N.III)

Comprises very deep, imperfectly drained soils derived from colluvial and alluvial material occurring on very gently sloping (1-3%) valley land. The pedons have dark grayish brown, moderately fine textured A horizon grading to light olive gray moderately fine textured B horizon. The soils are slightly eroded.

Nicobar valley series is a member of fine clayey mixed hyper thermic family of Typic Ochraqualfs.

Typifying pedon: Nicobar Valley clay loam

(Colours are for dry soils unless otherwise noted).

Horizon	Depth (cm)	Description
A1	0-19	Olive brown (2.5Y 4/4 moist) silty clay loam; moderate subangular clods; slightly hard; very sticky; very plastic; abundant fine and medium roots; cracks present, common, fine and medium pores, gradual smooth boundary.
B21t	19-59	Olive gray (5Y 5/2 moist) silty clay loam; moderate, medium subangular blocky, slightly firm, slightly hard; very sticky; very plastic; few, fine medium yellowish brown (10 YR 5/6) mottles; abundant roots, common, fine medium pores, crackes present, thin patchy skin on ped faces; clear, smooth boundary.
B22t	59-86	Light olive gray (5Y 6/2 moist) silty clay moderate, fine subangular blocky structure; to massive; firm, slightly hard, very sticky; very plastic, few fine pores; common, firm to fine-light gray (5Y 7/1) and common medium

Horizon	Depth (cm)	Description
		yellowish brown (10YR 5/6) mottlings, thin patchy clay skin on ped faces; clear smooth boundary.
B3t	86-150	Light olive gray (5Y 6/2) silty clay; moderate, medium angular blocky structure; firm, hard; common, fine faint gray (5Y 7/1) and few fine yellowish brown (10YR 5/6) mottlings; thin patchy clay skins along vertical fracture planes.

Range in characteristics

Solum depth is very deep. Surface soil colour is olive brown in hue 2.5Y with value 4 to 5 and chroma 4 to 5; texture clay loam. Subsoil colour ranges from olive gray to light olive gray to light brownish gray. The texture is clay loam. The clay content increases with depth and reaches maximum in B22t horizon.

Drainage and permeability

Imperfectly drained; permeability moderately slow to slow; Run off is moderate.

Use and Vegetation

Mostly under evergreen forest vegetation.

Distribution and Extent :

Occur extensively on valley lands in Great Nicobar Islands.

Series established and type location

Nicobar valley series :380 km. south of Port Blair, 6°58' north latitude and 93°54' east longitude at an elevation of 7 m. M.S.L.

2. Colour of the soils and their clay fraction

Soil colour is the most obvious and easily determined of soil characteristics. Although it has little direct influence on the functioning of the soil, one may infer a great deal about a soil if it is examined with other observable features.

Soils under present study follow the gradation change down the slope and the drainage pattern as in other two sequence described earlier. The effect of various treatments on the colour of the soils and clay is discussed below (Table 25 and 26).

Colour in relation to Organic matter

Oxidation of organic matter with hydrogen peroxide did not show any significant change in the soil colour. When the samples were pretreated with dilute hydrochloric acid, the oxidation of organic matter by hydrogen peroxide shows no appreciable change in the soils of the upper slope profiles but lower member turn greyish brown. The change is mostly confined to value and chroma. Thus the darker shade of the soil may probably due to the organic matter in the presence of calcium.

Table 25. Colours of the Soils

NICOBAR SEQUENCE

Soil Series	Depth (cm.)	Field Observation	On air dried	On removal $CaCo_3$ and organic matter.	On removal of free oxides.
NI	0-14	5 YR 4/3	5 YR 5/3	5 YR 5/2	5 YR 5/1
	14-50	5 YR 6/3	5 YR 6/2	5 YR 6/3	5 YR 6/1
	50-79	5 YR 5/6	5 YR 5/5	5 YR 4/4	5 YR 4/2
	79-150	5 YR 6/4	5 YR 6/4	5 YR 6/3	5 YR 6/2
N II	0-17	10 YR 3/4	10 YR 3/3	10 YR 3/2	10 YR 3/1
	17-48	10 YR 5/4	10 YR 5/3	10 YR 5/3	10 YR 5/1
	48-91	7.5YR 5/4	7.5YR5/4	7.5YR5/4	10 YR 5/1
	91-150	10 YR 6/6	10 YR 6/4	10 YR 6/4	10 YR 6/1
N III	0-19	2.5 Y 4/4	2.5 Y 4/3	2.5 Y 4/2	2.5 Y 4/1
	19-59	5 Y 5/2	5 Y 5/2	5 Y 5/2	5 Y 5/1
	59-86	5 Y 6/2	5 Y 6/2	5 Y 6/2	5 Y 6/1
	86-150	5 Y 6/2	5 Y 6/2	5 Y 6/2	5 Y 6/1

Colour in relation to free oxides in the soil

Removal of the free oxides from the soils results in the change of colour to reddish grey to grey in the upper slope member (N.I), very dark brown to very dark grey in the mid series (N.II) and dark greyish brown to dark grey in Valley series (N.III).

There is no marked change in hue of the soils and the variation is observed in value and chroma. Yellowish colour of the soil disappears as a result of removal of free oxides.

Table 26. Colour of the clay fraction

NICOBAR SEQUENCE

Soil series	Depth (cm)	Original	On removal of free oxide
N.I	0-14	5YR6/3	5YR6/2
	14-50	5YR6/4	5YR6/2
	50-79	5YR5/4	5YR5/2
	79-150	5YR6/4	5YR6/2
N.II	0-17	10YR3/3	10YR3/2
	17-48	10YR5/3	10YR5/1
	48-91	10YR5/4	10YR5/2
	91-150	10YR6/4	10YR6/2
N.III	0-19	2.5Y4/4	2.5Y4/2
	19-59	5Y5/4	5Y5/3
	59-96	5Y6/8	5Y6/3
	86-150	5Y6/4	5Y6/2

The colour of the clays are the same as that of the soil and it may be possible that the colour of the soil is influenced by the colour of their mechanical fractions particularly the clays as reported earlier by Joshi (1950).

The change of colour due to removal of free oxide as seen from the table indicates there is fairly good relation between the amount of free oxides and colour of soil. It appears that the free iron in different state of hydration is the principal cause for their colouration.

The results are in agreement with those of Stace (1956), Kelley et al. (1939) and Joshi (1945). On the whole, it may be possible that a number of factors are responsible for the soil colour. In the light coloured soils free iron in different state of hydration in absence of high organic matter, imparts the colour to the soils, whereas organic matter, exchangeable calcium and free iron are the principal factors for the colour of the dark greyish brown soils, Joshi (1950) who worked on the soils, also considers the effect of many factors for their colour and states that it is the intrinsic property of the clay which influences the colour of the dark coloured soils while all the fractions influence the colour of the light coloured soils.

3. Mechanical composition of the soils

Mechanical constituents of the soils of the sequence furnished in table 27 show similar gradation in toposequence as observed in Diglipur Sequence and Rangat Sequence.

There is increase in detritus content in the upper slope members N.I and N.II than in the lower members (N.III) where it is completely absent. The presence of graval in the higher slopes member also corroborate the statement of Radwanski et al.

(1959). They also recorded that all upland soils are high in stones and gravels.

4. Soil reaction

The pH values indicate that the soils are acidic in reaction and shows more leaching effect on the upper slope members than the lower ones. There is gradational increase in the pH with the decrease in slope. The reasons are already explained in earlier section dealing with Diglipur sequence and Rangat Sequence.

Mechanical Constituents

Mechanical constituents of the soils show characteristic features in the distribution of various soil constituents in the profiles of the sequence. The distribution of mechanical separates in various soil profiles maintains gradational change in the composition of soils along the slope and resembles to a great extent the soil sequences described and discussed earlier. The clay content of the surface soil increases as the slope decreases. The upper slope members N.I andN.II show relatively low content of clay which increases with depth within the profile.

Higher slope members are considerably higher in the coarse sand, increasing down the profile whereas lower slope members are much lower in coarse sand content.

Table 27. Analytical data : Mechanical Constituents of Soil
(Expressed in percentage on oven dry basis)

NICOBAR SEQUENCE

Geomorphic Unit	Soil Series	Horizon	Depth (cm)	Ph (1:1.5)	Organic Carbon	Gravel	Coarse Sand 2-0.2 mm.	Fine 0.2-0.2 mm.	Silt 02-.002 mm.	Clay (∠0.002) mm.
Medium Hill Upper Slope	N I	A1	0-14	5.8	0.95	3.2	5.52	34.22	35.12	25.14
		B21t	14-50	5.9	0.85	5.7	3.9	26.28	38.01	31.81
		B22t	50-79	6.1	0.25	7.5	4.33	24.52	39.12	32.03
		B3	79-150	6.2	0.17	6.1	3.72	33.25	33.89	29.14
Medium Hill mid-Slope	N II	A1	0-17	6.0	1.06	-	11.18	19.38	38.56	30.88
		B1	17-48	5.9	0.85	2.3	8.49	20.46	39.00	32.05
		B2t	48-91	6.1	0.31	15.2	5.54	18.34	42.00	36.12
		Bc	91-150	5.9	0.15	18.1	1.90	26.64	41.00	30.46
Valley	N III	A1	0-19	6.5	1.15	-	4.27	20.63	40.12	34.98
		B21t	19-59	6.6	0.65	-	3.70	16.90	42.09	37.31
		B22t	59-86	6.7	0.41	-	3.36	17.82	39.67	39.15
		B23t	86-150	6.5	0.21	-	0.33	15.34	43.13	41.20

The findings show the active migration of the finer particles down the slope and represents typical gradation of the mechanical separates related largely to the topographic situation.

Organic Carbon and Nitrogen

Organic carbon content of the soil is appreciable in the soils and shows a decrease down the profile. There is an accumulation of organic matter in the surface layers. Highest organic matter accumulation is observed in the Nicobar mid-series and may be due to the leaf fall and accumulation of leaf litter from the forest.

Carbon-Nitrogen ratio (Table 28) shows higher values in the surface soils in the profiles of the toposequence. This increase in the surface layer may be due to the accumulation of leaf litter and other additions of highly cellulosic materials of the vegetation. Another explanation may be the one discussed earlier for Diglipur sequence and Rangat Sequence. The trend of results is in consonance with the observation of Hallsworth et al. (1953), Muir et al. (1957) and Agarwal et al. (1957).

Cation Exchange capacity of soils

Cation exchange capacity of soils (Table 29) show a similar gradation as that of topography. The surface soils of different profiles show an increase in CEC down the slope. The high CEC of the soils is suggestive of the type of clay mineral. This further confirmed during the X-ray analysis of clays. CEC maintains a proportional increase with clay content of the soil in different profiles.

Table 28. C/N Ratio of the Soil
(Expressed in percentage on oven dry basis)

NICOBAR SEQUENCE

Soil series	Depth (cm)	Organic carbon	Organic nitrogen	C/N Ratio
N.I	0-14	0.95	0.082	11.5
	14-50	0.85	0.075	11.3
	50-79	0.25	0.025	9.9
	79-150	0.17	0.018	9.1
N.II	0-17	1.05	0.114	9.2
	17-48	0.85	0.093	9.1
	48-91	0.31	0.036	8.4
	91-150	0.15	0.018	8.1
N.III	0-19	0.75	0.049	15.8
	19-59	0.65	0.070	9.2
	59-86	0.41	0.048	8.4
	86-150	0.21	0.025	8.3

Exchangeable cations

The variation in the exchangeable cation presents a characteristic pattern in the soils of the toposequence. Calcium is found to dominate in the exchange complex in all the soils of the

Table 29. Cation Exchange Capacity and Exchangeable Cations of the Soil (Expressed in m. e. Percent on oven dry basis)

NICOBAR SEQUENCE

Soil Series	Depth (cm)	CEC m.e. 100g	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	TOTAL	Base Saturation (Percent)
Nicobar upper Series (NI)	0-14	17.9	8.20	5.72	0.27	0.03	14.22	79.44
	14-50	23.1	12.37	7.58	0.36	0.20	20.61	88.78
	50-79	22.1	11.88	7.56	0.26	0.33	20.03	90.63
	79-150	20.1	9.66	6.61	0.20	0.45	16.92	84.17
Nicobar mid Series (NII)	0-17	18.1	9.05	6.18	0.26	0.31	15.80	87.29
	17-48	21.05	11.02	6.46	0.29	0.28	18.05	85.74
	48-91	23.65	12.26	7.14	0.29	0.47	20.12	85.05
	91-150	19.68	10.26	5.27	0.18	0.33	16.23	82.46
Nicobar valley Series (NIII)	0-19	21.90	10.09	7.66	0.35	0.40	18.50	84.47
	19-59	24.20	12.32	8.02	0.42	0.34	21.10	87.19
	59-86	23.40	11.20	8.30	0.41	0.29	20.20	86,32
	86-150	28.80	16.76	8.12	0.29	0.46	25.63	88.99

sequence. Exchangeable calcium increases down the slope as in other two sequences described earlier.

Exchangeable magnesium also shows increase down the slope as also down the profile.

There is gradual increase in the exchangeable sodium from the slope as well as within the profile. The percentage of sodium in the exchange complex does not show much variation within the profile as well as between the profiles.

Exchangeable potassium is only a very small part of the exchangeable cations and follows the toposequence as that of exchangeable sodium.

Chemical composition of the clay fraction

Chemical composition of the clay fraction (Table 30) of the soils of Nicobar Sequence maintains its relationship with the topography and drainage pattern. The variation in the distribution of the constituents down the slope is well marked, showing either decrease or increase. The upper slope members are more sesquioxidic than the lower ones. Each constituent is discussed below.

Silica

The silica contents of clay fractions of the surface soils increase down the slope from upper member (N.I) to lower member (N.III). Silica constitutes major portion of the clay fraction. Drainage appears to be the principal cause of loss of Silica along the slope. Relatively higher percentage of Silica content

Table 30. Chemical Constituents of Clay Fraction.
(Expressed as percentage on ignited basis)

NICOBAR SEQUENCE

Name of Series	Depth Cms.	Moisture	Loss on ignition	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	TiO_2	MnO	CaO	MgO	K_2O	$\frac{SiO_2}{R_2O_3}$
Nicobar	0-14	8.10	10.75	46.10	35.40	24.61	10.45	0.45	0.21	2.50	2.46	2.98	2.51
Upper Series	14-50	8.50	11.82	46.21	35.21	23.91	10.94	0.36	0.09	1.71	2.41	2.71	2.54
(N I)	50-79	8.90	11.30	46.56	35.19	24.51	10.17	0.51	0.10	2.19	2.21	2.61	2.55
	79-150	8.60	10.31	46.78	36.10	25.10	11.00	0.59	0.13	2.08	2.41	2.41	2.47
Nicobar Mid	0-17	8.21	11.72	46.00	34.78	22.12	12.45	0.21	0.21	1.81	2.70	2.51	2.66
Series (N II)	17-48	8.41	11.30	47.00	35.61	23.29	12.05	0.27	0.19	1.92	2.42	2.42	2.60
	48-91	8.52	10.40	47.01	35.60	23.40	11.82	0.33	0.30	2.31	2.72	2.30	2.58
	91-150	8.90	10.21	46.99	35.71	22.31	12.38	0.32	0.23	2.10	2.67	2.00	2.63
Nicobar Valley	0-19	8.02	11.82	47.80	34.51	22.68	11.69	0.14	0.13	2.21	2.81	2.12	2.69
Series (N III)	19-59	9.21	8.00	48.10	34.01	22.01	11.59	0.12	0.11	2.31	2.91	2.34	2.76
	59-86	9.81	11.20	47.11	34.70	22.41	12.08	0.21	0.08	2.41	2.98	2.41	2.66
	86-150	10.21	11.01	47.21	34.56	21.31	11.94	0.31	0.07	2.52	2.99	2.81	2.78

in the clay fractions is suggestive of the minerological composition of the clay fractions in the soils.

Sesquixodes

Upper surface members present higher content of Sesquioxide. There is a tendency to decrease the sesquioxide down the slope. The decrease in the sesquioxide below certain depth may be due to the decrease in the iron content.

Contents of iron and alumina follow the toposequence. By comparison the clays of the upper slope profiles are higher in alumina than those of the lower ones.

Variation in the iron content of different profiles follow the topographic sequence, decreasing down the slope from the upper slope member to lower slope member. Leaching is manifested in the accumulation of iron oxide in profile at certain depths. A more intimate relationship of Silica, iron and alumina is shown in their molar ratios presented in Table 30. Molar ratios follow the topographic sequence. The silica-sesquioxide ratio is suggestive of the type of clay mineral.

Titanium contents of the clay fractions follow the toposequence. There is a decrease in the titanium content from upper member to the lower member of the sequence.

Manganese in the clay fraction of this toposequence resembles that of the toposequence described earlier. Low content of this form in lower profile may be due to cultivation effect which makes the manganese more mobile.

Calcium and Magnesium

Calcium contents of the clays of the sequence follow the toposequence, increasing down the slope. The calcium content of the upper slope member is low as compared to the lower slope members.

Magnesium follows the similar pattern of gradation as that of Calcium. Magnesium is more or less uniformly distributed in the poorly drained soils.

Potassium

Potassium content of the Soil present a decreasing trend down the slope. This indicates that this is gradually leached out.

Cation exchange capacity of the clay fraction

Cation exchange capacities of clay fractions presented in the Table 31 show a gradation which is typical of the toposequence on which they occur, and resembles closely the relation maintained by earlier sequences. Cation exchange capacities increase gradually with the slope. Cation exchange capacity within the profile show slight increase down the profile. The effect of drainage is clearly evident on CEC of the clays. More well drained the soil, less cation exchange capacity and *vice versa*.

Table 31. Cation exchange capacity of the clay fractions.
(Expressed as m.e. per 100 gm of oven dry clay)

NICOBAR SEQUENCE

Soil series	Dept (cm)	Cation exchange capacity
Nicobar upper series (N.I)	0-14	65.41
	14-50	65.61
	50-79	66.70
	79-150	66.41
Nicobar mid series (N.II)	0-17	66.81
	17-48	67.01
	48-91	68.18
	91-150	68.21
Nicobar valley series (N.III)	0-19	68.30
	19-59	69.80
	59-86	69.10
	86-150	70.21

Primary minerals of the fine sand fractions

The distribution pattern of primary minerals in Nicobar sequence is presented in Table 32 and 33.

As in the earlier two sequences light separates constitute major portion of the fine sand fractions. The resistant minerals quartz and orthoclase feldspar constitute the major portion of the light fraction.

Quartz

Quartz constitutes about 50 per cent of the fine sand fraction. Angular fresh grains of quartz of small to big size are present in the upper members (N.I and III) of the sequence whereas smooth and rounded grains are present in lower member (N.III). The presence of rounded fresh quartz grains in valley sequence (N.III) may be possible if the parent material had been transported down from the upper region.

Feldspar

Orthoclase feldspar which is another important primary mineral is also present more or less in the same proportion of quartz but differs in alteration. The degree of weathering is higher in the upper members. N.I and N.II than the valley soil N.III. In N.II, the alteration product is about 50 per cent which is indicative of the transition stage from N.I to N.III. Thus, alteration of feldspar decreases from upper slope to lower slope members of the toposequence. Few grains of plageoclase are present in some of the samples, but not maintain any regularity. Few microline minerals are detected only in the surface.

Table 32. Distribution of Light and Heavy mineral in fine sand fraction (Nicobar sequence)

(Expressed in percentage)

Soil series	Depth	Light fraction	Heavy fraction
Nicobar upper series (N.I)	0-14	97.7	2.3
	14-50	93.3	6.3
Nicobar mid series (N.II)	0-17	97.5	2.7
	17-48	93.9	6.1
Nicobar valley series (N.III)	0-19	93.3	6.7
	19-59	96.1	3.1

Micaceous mineral

Mica is present in all the soils except in the valley soil (N. III) with its typical interference colours.

Opaque minerals

These are mostly of ilmenite and magnetite and are comparatively more in upper members N.II. They are medium size, rounded and they are mostly black in colour. Few grains are slightly reddish and yellow in reflected light. Increased reddish colour in the soils of upper members may be due to the iron content. The presence unweathered iron ore may provide an indication of higher degree of weathering.

Zircon

Zircon grains increase gradually down the slope and are proportionately higher in valley soil member N.III. It is often

Table 33. Mineral Composition of the Fine Sand Fractions.
(Expressed in mutual Percentage)

NICOBAR SEQUENCE

Name of Soil Series	Depth in Cms.	Light Minerals Q	OF	PF	M	MM	BM	C	Heavy Minerals Q	Z	T	H	K	S	A	Ap	G
Nicobar Upper	0-14	53	37.4	4.1	1	4.5			33.1	31.4	14.1	11.0	1.6	1.9	2	2.9	2.0
Series NI	14-50	51	44.1	2.8		2.1			41.2	35.2	12.3	9.9	1.4				
Nicobar Mid Series N II	0-17	43	50.7	2.2		4.1			38	34,5	6.2	9.1	1.2	1.1	1.0	3.2	5.2
	17-48	52	43.5			4.5			35	34.2	7.1	11.2	1.7	1.6	1.1	2.0	4.1
Nicobar Valley Series N III	0-19	47	48.9	4.1					37	37.0	6.2	6.8	5.1	1.1		5.8	1.0
	19-59	54	41.0	.4	1.0				40	47.5	4.1	5.2	4.3	1.8		7.1	

<u>Reference</u> :

Q. Quartz, OF. Orthoclase Feldspar, PF. Plagioclase Feldspar, M. Microcline,

BM. Biotite, C. Coated, O. Opaque, Z. Zircon, T. Tounmaline, H. Honblende,

K. Kynite, S. Sillimanite, A. Anatase, Ap. Apatite, G. Garnet.

present in very minute crystals. Coloured and often rounded zircons on the other hand indicates the tertiary sediments.

Tourmaline

Tourmaline decreases down the slope. They are of different thickness and mostly platy grain.

Hornblende

Hornblende is present throughout the sequence with a decrease along the slope. They appear to be foliated like leaves and in green colour.

Kyanite and Sillimanite

Kyanite is present in very small quantity and is distributed throughout the sequence. They are typically bladed crystals with irregular termination. Sillimanite constitutes a very minor fraction of the non-opaque minerals.

Apatite

Apatite mineral distribution is very few and relatively higher in surface layer. They are rounded with pitted surface.

Mineral distribution gives enough evidence for the inference of the uniform nature of parent materials from which these soils are developed. Sedimentary formations have been formed from weathering and have ultimately been deposited in the area. Soils might have been formed from these products of first cycle of weathering. This may be the reason for such low proportion of heavy minerals. However, the uniform mineral assemblage shows the uniformity of parent materials. The parent material which is sedimentary in nature is further influenced and topography and external agencies like run off. The presence of smooth and roundedd minerals is another indicator to show the causes that led to the formation of different members of soils. The findings of other sequence are also of similar nature.

Minerological make up of the clay fraction

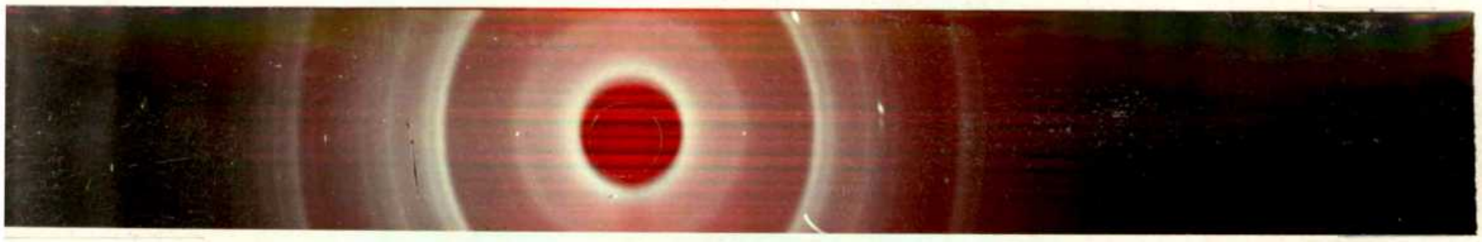
I. Identification of clay minerals by staining test

Clay minerals in the clay fractions were identified by the preliminary test following the staining process suggested by Richard C. Mielenz (1950). The minerological make up of the clay fraction identified is furnished in Table 34.

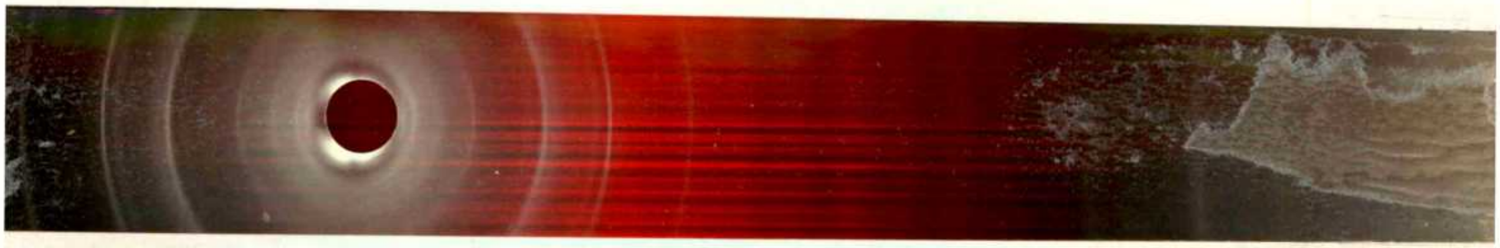
Table 34. Minerological make up of the clay fraction (Staining Test)

NICOBAR SEQUENCE

Soil series	Depth (cm)	Montmorillonite	Illite	Kaolinite
Nicobar upper series (N.I)	0-14	Present	-	Present
	14-50	Present	-	-
Nicobar mid series (N.II)	0-17	Present	Present	-
	17-48	Present	Present	-
Nicobar valley series (N.III)	0-19	Present	Present	-
	19-59	Present	Present	-



N I NICOBAR UPPER SERIES



N II NICOBAR MID SERIES

N III NICOBAR VALLEY SERIES

PLATE XV- X-RAY DIFFRACTION PHOTOGRAPHS OF SOME CLAY SAMPLES OF NICOBAR SEQUENCE

Presence of montmorillonite is observed in the clay fractions of all the three profile of the toposequence (N.1, N.II and N.III). Illite is present in the Nicobar mid series (N.I) and Nicobar valley series (N.III). Kaolinite is present in the surface soil of Nicobar upper series. The general trend of observation is similar to that of the findings of X-ray diffraction and differential Thermal Analysis.

2. X-ray diffraction Analysis

The clay fractions of the surface soils of Nicobar sequence were analysed for the crystalline components by the X-ray diffraction technique. X-ray diffraction pattern of few samples are shown in Plate XV. The distribution of different clay minerals in the three soils of the toposequence from the upper member N.I to N.III are presented in the table 35.

The presence of montmorillonite in all the profiles of the sequence and other supporting evidence of chemical data are the same as in Dighipur sequence. Whereas there is little variation in the distribution pattern of kaolinite and illite in the three profiles of the toposequence from upper member (N.I) to the valley (N.III) through N.II in the mid series, the presence of kaolinite clearly shows a decreasing tendency from the upper member (N.I) to the valley profile (N.III). Illite is present in trace from the mid series (N.II) of the sequence to valley series (N.III) in association with montmorillonite. The distribution of kaolinite and illite are largely in toposequence and are closely associated with drainage conditions and other features like topography, soil wash due to surface run-off from the upper to lower members.

Table 35. Crystalline components of the clay fraction (X-ray analysis)

NICOBAR SEQUENCE

Soil series	Depth (cm)	Montmorillonite	Illite	Kaolinite
Nicobar upper series (N.I)	0-14	++++++	-	+++
	14-50	++++++	-	+++
Nicobar mid series (N.II)	0-17	++++++	+++	+++
	17-48	++++++	+++	++
Nicobar valley series (N.III)	0-19	++++++	+++	++
	19-59	++++++	++	++

+ Relative abundance
- Absence
++++++ Major (25-50%)
+++ Trace (5-10%)
++ Small amount ($\angle$ 5%)

3. Differential Thermal Analysis

Clay minerals from different profiles of the Nicobar toposequence were identified by Differential Thermal Analysis. DTA Curves of some of the clay samples in the three profiles of the toposequence are furnished in Plate XXI. The distribution of different clay minerals in the soils of toposequence (N.I, N.II and N.III) are presented in Table 36.

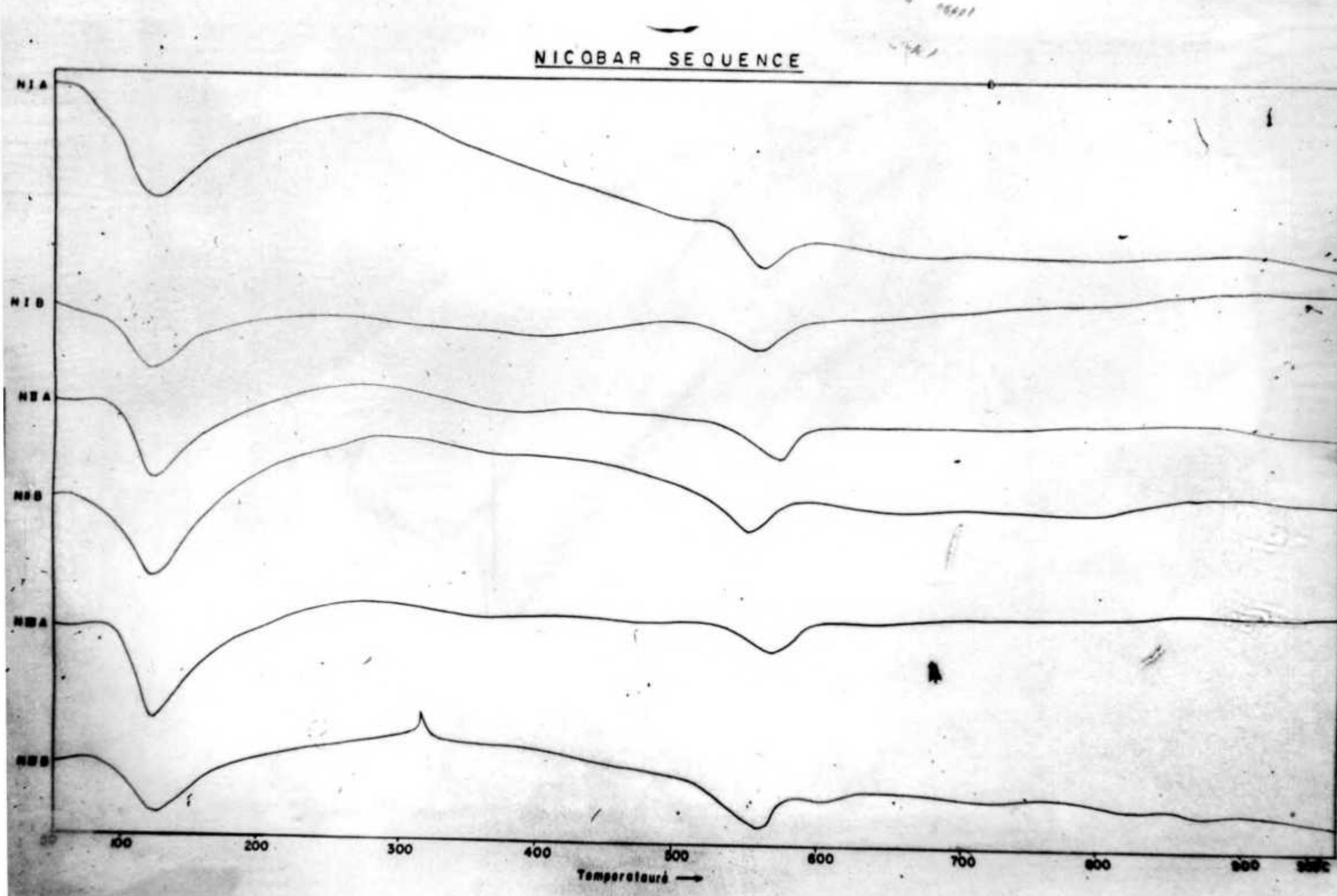


PLATE XII DIFFERENTIAL THERMAL ANALYSIS CURVES OF SOME CLAY SAMPLES - NICOBAR SEQUENCE

NI NICOBAR UPPER SERIES. A 0-14 cm B 14-50 cm.

NII NICOBAR MID SERIES. A 0-17 cm B 17-48 cm.

NIII NICOBAR VALLEY SERIES A 0-19 cm. B 19-59 cm.

Table 36. Crystalline components of the clay fraction (Differential Thermal Analysis)

NICOBAR SEQUENCE

Soil series	Depth (cm.)	Montmori-llonite	Illite	Kaolinite	Magnatite
Nicobar upper series(N.I)	0-14	++++++	+++	-	+++
	14-50	++++++	+++	-	+++
Nicobar mid series (N.II)	0-17	++++++	+++	-	-
	17-48	++++++	-	-	-
Nicobar valley series (N.III)	0-19	++++++	-	-	-
	19-50	++++++	+++	-	-

+	Relative abundance
-	Absence
++++++	Major (25-50%)
+++	Trace (5-10%)

Montmorillonite is found to be relatively of major occurrence in all the soils of toposequence. Illite is present in trace in all the profiles of the sequence. Endothermic peaks are observed at 130°C and 570°C. Exothermic hump occurs within the range of 200°C - 350°C, giving an inference of the presence of montmorillonite, illite and magnatite (Trace).

Kaolinite is not identifiable from the recorded curves. It may be due to the poor crystallination of the kaolinite present in various soils.

General distribution trend of clay minerals in different soils of the toposequence maintains its close relationship with the parent material, topography and other supporting evidence discussed earlier under X-ray diffraction for different soils.

D. GENERAL DISCUSSION

Three toposequences situated wide apart were discussed in detail in the previous section. Each of these three sequences comprises three distinct members in specific topographic situation of medium hills, viz., upper, middle and valley. Each member of the catena represents a soil series characterising the pedogenic processes by which it was developed under the peculiar oceanic climatic condition of the Island.

Soil characteristics

Upper Series (D.I, R.I, N.I)

Comprises very deep, moderately well drained, derived from dominantly sandstone and shale parent materials with intrusions of volcanic rocks and igneous material, occurring on Steep (25-33%) slope of medium hills. Pedons have dark reddish brown to reddish brown, medium textured A horizon grading to light reddish fine textured brown B horizon with reddish yellow, pink white mottles. Soils are under land capability class IV moderately eroded and under forest vegetation.

Eluviation of clay is pronounced. These soils are medium to slightly acid in reaction. Soils are relatively higher in sesquioxide and higher state of oxidation and iron imparts light reddish colour to the soils of upper slopes. They are sticky and plastic. Silica sesquioxide ratios are higher indicating the minerological make up as dominantly montmorillonite in association with illite and kaolinite with poor crystallinity. Cation exchange capacity is high. Clay fractions are relatively high in calcium and magnesium. Base saturation is also high. Quartz and partially weathered Orthoclase feldspar fractions are also on the high side. The relative reduction in the SiO_2/R_2O_3 ratio in comparison with the lower members of the catena, proportionately high content of sesquioxide are indicative of the advancing process of laterization.

Mid Series (D.II, R.II, N.II)

Comprises very deep, moderately drained soil derived from dominantly sandstone and shale parent materials with intrusions of volcanic rocks and igneous material, occurring on strongly sloping (10-15%) middle slope of medium hills. Pedons have dark yellowish brown moderately fine textured A horizon grading to brownish yellow, moderately fine to fine textured D horizon with light yellowish brown mottlings. Soils are moderately eroded and under horticultural and plantation crops and are under land capability class III.

Eluviation of clay is evident. Soils are medium acid (pH 5.6) to slightly acidic (pH 6.2). Soils are sticky and plastic. Morphological and chemical properties of the soils indicate that these soils are in the transition zone from the upper slope to the valley. Silica and sesquioxide contents are relatively low and silica-sesquioxide ratios are higher. Calcium and Magnesium status are high. Cation exchange capacities are also high. The exchange complex is saturated with exchangeable cations. Quartz and partially weathered orthoclare feldspar present in the light sand fraction. The dominance of montmorillonite with trace of illite and kaolinite is the characteristic feature. X-ray diffraction and D.T.A. show the crystallinity of the minerals are poor.

Valley Series (D.III, R.III, N.III)

Comprises very deep, imperfectly drained soils of colluvial and alluvial formation, derived from parent materials of sandstone, shale, with intrusions of volcanic and igneous rocks, occurring on very gently sloping (1-3%) valley land. The Pedons have very dark greyish brown, moderately fine textured A horizon grading to light brownish grey to grey, fine textured B horizon. Soils are moderately eroded and under cultivation of field crops.

Soils are slightly acidic (pH 6 - pH 6.7). They are sticky and plastic. The clay content is highest in the sequence. Silica content is high and sesquioxide content is low. Calcium and magnesium are high. Cation exchange capacity is high. The exchange complex is saturated with exchangeable cations. The dominance of montmorillonite with traces of illite and kaolinite is more prominent in the soils of this topographic situation. X-ray and D.T.A. studies of mineral make up the soil reveal the crystallinity of the clay minerals are poor.

Parent Material

Geologically the Islands are of Sedimentary origin. Petrographic studies have shown uniformity in the parent material of the soils of three catenary associations, though the changes are largely attributed to topography and drainage. Investigation of the soils reveal that though they show changes in their morphology and chemical composition, the basic features have not shown much difference. The environmental factors peculiar to these oceanic Islands, the coral deposits, Calcium carbonate accumulation, heavy rainfall, tropical dense forest, nearness to sea coast, influence of past volcanic action etc., might have played an important role in the soil formations and its minerological make-up.

<u>Topography and Drainage</u>

Soils of the lower slope members are more basic than soils of the higher slope members. The contents ferric oxides also differ in the upper and lower slope members. The lower slope members have relatively higher C.E.C. than the upper slope members.

The Silica sesquioxide ratios are high in all the sequences and shows an increasing tendency towards the lower ones.

The data presented indicate that the clay minerals formed in the sequences is influenced by the weathering environment, as controlled by the topography and drainage. X-ray diffraction and Differential Thermal Analysis of the samples have shown that the clay minerals are composed of mixed layers of montmorillonite and illite (Grim and Rowland, 1942). There is a strong geologic evidence of a strong tendency towards fixation of Potassium due to preferential absorption of potasium clay minerals as well as by the tendency for mica or mica like mineral to develop thereby also fixing K_2O. This behaviour and wide spread occurrance of montmorillonite in association with illite is also reported by Ross and Hendricks (1945). The formation of montmorillonite mostly beidellite as seen from Differential Thermal Analysis might have taken place during weathering of ferromagnesium minerals and feldspars of the parent rock are decomposed simultaneously, thus releasing ferrous and ferric iron, magnesium, alumina and silica. In general, the values for iron and magnesium are higher and this leads to the formation of montmorillonate. It is also probable as reported by Kerr et al. (1950) that montmorillonite contains Zirconium and Calcium (2.4%), the latter occurs in clay lattice. Relatively high Calcium content in the clay fraction is another factor to be considered.

Differential Thermal Analysis has also shown the presence of montronite which is the iron rich member of the montmorillonite group in the clay samples of the sequence. This is rich in iron and silicon with alluminium and calcium as secondary importance.

The illite group mineral appearing as trace is probably the most complex among clays. The values for potassium is high since the inter layer ion is potassium rather than calcium as in montmorillonite. Paul, F. Kerr (1950) further observed that the most important constituents of sedimentary material from the geochemical point of view are clay minerals formed as a result of hydrolysis and under hydrothermal conditions. Calcium, Magnesium and Sodium are significant in montmorillonite and beidellite, Ferric iron in nontronite and magnesium in Sepionite and attapulganite. It is further reported that the occurence of montmorillonite group in abundance in areas of volcanic influence, recent marine deposits and in hydrothermal veins and mineral deposits, and also occurance of montmorillonite in association with illite (Hydromica) and Kaoline (Paul F. Kerr, et 1950)

It may be inferred from the observations that the pattern of soil development described are greatly due to differences in weathering under different drainage conditions (Milne 1935). The soils are formed in a dynamic equilibrium with their environment and base status of each soil as a result of the balance between loss of leaching and input from weathering and groundwater (Hallsworth et.al 1952). The Characteristics of these associated soils are in toposequence in which they occur and can be considered to establish well in catenary sequence.

Soil Classification

The Pedologist regards soil in terms of weathered and altered upper part of the unconsolidated material. A soil profile consists of a succession of horizons. The surface horizons are formed by the interaction of rock material with organic material in the atmospheric environment. The soil formation is based on the climate, vegetation, parent material, topography and time (Raymond, N.Yong and Benno P.Warkentin, 1975).

There are many method for classification of soil. The choice of method depends upon the specific use intended for the soil. Geologic classifications are mostly genetic but partly descriptive, mostly in terms of surfacial deposits. There is no universally accepted system of soil classification and nomenclature, comparable to that which exists for rock types or biological species. One national and two international systems have some measure of international recognition.

In 1960 the U.S. Soil Survey produced a scheme entitled "Soil classification. A comprehensive system. 7th approximation" usually known as "the 7th approximation" (Soil Survey Staff,1960).

The first international system originated when the Commission for Technical Co-operation in Africa (CCTA) produced in 1964 the Soil map of Africa 1:5000000. The Explanatory monograph to this, the work of the Belgian J.L.D' Hoore, contains a classification system that is an attempt to combine those of French (ORSTOM) and Belgian (INEAC) work in Africa. The only fully international scheme is that produced by the FAO in 1974 for use in their Soil map of the world.

CCTA Soil map of Africa and their system of classification (D'Hoore, 1968; Ahn, 1970) is a natural one and in large part genetic (except for the anomalous use of colour to subdivide ferralitic soils). The subdivision of groups into soiltypes is frequently on the basis of parent material. Non differentiated units are given to cover areas for which there is no information. Each soil type is defined by a descriptive paragraph setting out its morphological and analysed features, sometimes with qualitatives, together with the environment under which it occurs.

The FAO classification system is having a legend with two categories. The basis element is the soil unit. The units are combined on the basis of generally accepted principles of soil formation. In addition there are phases which may be applied to any soil unit. Although many of the soil groups are natural soil types, this is structurally an artificial classification.

The soil classification A comprehensive system, 7th Approximation is a classification according to natural relationships. The classification is hierarchical with six categories : Orders, sub Orders, great groups, sub groups, families and series. There are 10 orders, 47 sub orders and 225 great groups. A lengthy and precise terms. For each parameter employed there are precise quantitative limits given, together with the analytical procedures to be employed.

Most tropical soils of this region fall into orders of entisol inceptisol and Alfisols. Entisols lack horizons of pedogenetic origin; this class is used to cover not only alluvial soils but also sands with little profile development and rocky soils of mountaneous areas. Inceptisols lack an argillic horizon; whilst primarily belonging to the temperate zone they include a tropical suborder tropepts. Alfisols and Ultisols have an argillic horizon, base saturation being above 35 percent in Alfisols and below in Ultisols (with some exceptions).

In India, since this classification system has been accepted with necessary changes to suit local conditions, an attempt is made to classify the soils of three toposequence under investigation under the 7th approximation.

The taxonomic classification of different soils of three sequences reveal all the soils belong to the order Alfisol. The soils show slight change in the sub order. All soils upper and mid slope come within the limits of Udalfs, whereas the soils of Valley D III, R III and N III come within Aqualfs. The distribution of soils under great group is in three category i.e. Hapludalf (D I, D II; R I, R II; and N II).
Ochraqualfs (D III, R III, N III) and
Paleudalf (N I).

In sub group level soils D I & R I fall into Mollic Hapludalfs; D II, R II, N II fall whi within TypicHaplufalf; D III, R III, N III fall within Typic Ochraqualfs; N I in Typic Paleudalfs. Classification at family level does not have any change.
All the soils come within Fine Clayey mixed hyperthermic.

The classification shows the similarity between soils of each catenary association. Bear (1964) also observed occurrence of Alfisols with montomorillonite in association with illite and Kaolinite.

Names of Taxa in each category

Order	Sub-order	Great Group	Sub-Group	Family	Series
Alfisol	Udalfs	Hapludalfs	Mollic Hapludalfs	Fine Clayey mixed hyper thermic	Diglipur Upper Series (D I)
Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Fine clayey mixed typer thermic	Diglipur mid-series (D II)
Alfisol	Aqualfs	Ocharaqualfs	Typic Ochraqualfs	Fine Clayey mixed hyper thermic	Diglipur Valley Series (D III)
Alfisol	Udalfs	Hapludalfs	Mollic Hapludalfs	Fine Clayey mixed hyper theric	Rangat Upper Series (R I)
Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Fine Clayey mixed hyper thermic	Rangat mid Series (R II)
Alfisol	Aqualfs	Ocharaqualfs	Typic Ocharaqualfs	Fine Clayey mixed hyper thermic	Rangat Valley Series (R III)
Alfisol	Udalfs	Paleudalfs	Typic Paleudalfs	Fine Clayey mixed hyper thermic	Nicobar upper Series (N I)
Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Fine Clayey mixed hyper thermic	Nicobar mid Series (N II)
Alfisol	Aqualfs	Ocharaqualfs	Typic Ochnaqualfs	Fine Clayey mixed hyper thermic	Nicobar valley series (N III)

As the various classification systems brings out different properties there is substantial overlap between classes. It is, therefore, impossible to furnish exact equivalents, and correlation can only be achieved by reference to the properties of soil series.

Brief description of soils and their classification are furnished below :

1. Diglipur Sequence

a) Diglipur Upper series (D.I)

Comprises very deep, well drained soils derived from sandstone and shale parent material occurring on steep (25-33%) upper slope of medium hills. The pedons have dark reddish brown to reddish brown, medium textured A horizon grading to reddish brown to yellowish red moderately fine textured B horizon. The soils are moderately eroded.

Diglipur upper series is a member of fine clayey mixed hyper thermic family of Mollic Hapludalfs.

b) Diglipur mid series (D. II)

Comprises very deep, moderately well drained soils derived from sandstone and shale parent material occurring on strongly sloping (10-15%) mid-slope of medium hills. The pedons have dark yellowish brown moderately fine textured A horizon grading to yellowish brown toolive grey, moderately fine textured B horizon. The soils are moderately eroded.

Diglipur mid series is a member of fine clay mixed hyper thermic family of Typic Hapludalfs.

c) Diglipur Valley Series (D. III)

Comprises very deep, imperfectly drained soils derived from colluvial and alluvial material occurring on very gently sloping (1-3%) Valley land. The pedons have very dark greyish brown, moderately fine textured A horizon grading to light brownish gray to gray, fine textured B horizon. The soils are moderately eroded.

Diglipur Valley series is a member of fine clayey mixed hyperthermic family of Typic ochraqualfs.

2. Rangat Sequence

a) Rangat Upper Series (R.I)

Comprises very deep, well drained soils derived from sand stone and shale parent material occurring on steep (25-33%) upper slopes of medium hills. The pedons have dark reddish brown, medium textured A horizon grading to dark reddish gray to light reddish brown, moderately fine textured B horizon. The soils are moderately eroded.

Rangat upper series is a member of fine clayey mixed hyperthermic family of Mollic Hapludalfs.

b) Rangat mid Series (R.II)

Comprises very deep, moderately well drained soils derived from sandstone and shale parent materials occurring on strongly sloping (10-15%) mid slope of medium hills. The pedons have dark yellowish brown moderately fine textured A horizon grading to yellowish brown to grayish brown moderately fine to fine textured B horizon. The soils are moderately eroded.

Rangat mid series is a member of fine clayey mixed hyperthermic family of Typic hapludalfs.

c) Rangat Valley Series (R.III)

Comprises very deep, imperfectly drained soils derived from colluvial and alluvial material occurring on very gently sloping (1-3%) valley land. The pedons have dark grayish brown, moderately fine textured A horizon grading to grayish brown to light olive brown, moderately fine to fine textured B horizon. The soils are moderately eroded.

Rangat valley series is a member of fine clayey mixed hyperthermic family of Typic ochraqualfs.

3. Nicobar Sequence

a) Nicobar Upper Series (N.I)

Comprises very deep, well drained soils derived from sandstone and shale parent material occurring on steep (25-33%) upper slopes of medium hills. The pedons have dark reddish brown, medium textured A horizon grading to light reddish brown to brown moderately fine textured B horizon. The soils are moderately eroded.

Nicobar upper series is a member of fine loamy mixed hyper thermic family of Typic Paleudalfs.

b) Nicobar mid Series (N. II)

Comprises very deep, moderately well drained soils derived from sandstone and shale parent materials occurring on strongly sloping (10-15%) mid slope of medium hills. The pedons have dark yellowish brown, moderately fine textured A horizon grading to brownish yellow moderately fine to fine textured B horizon. The soils are moderately eroded.

Nicobar mid series is a member of fine loamy mixed hyper thermic family of Typic Hapludalfs.

c) Nicobar Valley series (N. III)

Comprises very deep, imperfectly drained soils derived from colluvial and alluvial material occurring on very gently sloping (1-3%) valley land. The pedons have dark greyish brown, moderately fine textured A horizon grading to light olive gray moderately fine textured B horizon.

Nicobar valley series is a member of fine clayey mixed hyper thermic family of Typic Ocraqualfs.

Soil moisture Regime, Soil Management and Crop production

Soils under investigation come within the perview of land capability classes II, III and IV as per the land capability classification provided in the soil survey Mannual (1970), India (Annexure IV and V). Soils of the three toposequences described earlier possess soil condition favourable for crop growth with the limitation that the fine textured soils in valleys, the sites D.III, R.III and N.III are subjected to excessive moisture and impeded drainage. While soils of upper and mid slopes are suitablefor plantation and other crops that need good drainage, the valley soils are suitable for semiaquatic crops like rice and other field crops.

Moisture condition

Most crops need well drained soil for better crop performance, whilst others can tolerate seasonal impedence. In depositional landscapes, site drainage impedence is a widespread limitation, whereas in erosional relief it is confined to valley floors. Profile drainage impedence, arising when rainfall intensity exceeds soil permeability, is common on clays containing an appreciable amount of 2:1 lattice mineral. Valley profiles of three sequences D.III, R.III and N.III are examples of this condition which experiences impeded drainage. It may be the practice to plant short duration field crops early in the dry season, on low catena sites that are water logged (D.III, R.III and N.III) in wet season, making use of the residual moisture. This may be considered as a labour intensive technology for making profitable use of resource while main cereal crop rice which is a semiaquatic crop is produced during main monsoon season (Kharif season) when soils are under water logged condition. Site drainage can be substantially further improved by developing a system of open ditches.

Soils of the upper sequence (D.I, R.I and N.I) and mid sequence (D.II, R.II and N.II) are relatively open textured with coarser material. The topographic situation with higher slope gradient facilitates rapid run off of these sites, maintains the external drainage and condition 'well drained' and internal drainage of the profiles 'moderately well drained'.

Soil Water Potential

Water holding capacity of the soils are high as seen from Table 37. Total suction, holding water in soil responsible for soil water potential possesses two components namely matric suction and osmotic suction. Matric suction which is associated with the physical properties of the matrix of pores and solid material which comprises the fabric of the soils. This suction pervades the whole soil system and tends to equilibrate the moisture status of the soil, but because the system is being constantly influenced by variables from outside, viz., precipitation, evaporation and transpiration, as equilibrium is rarely achieved. Soils under investigation is greatly influenced by the matric suction than osmotic pressure. Osmotic potential arising from the solutes are of less importance in the soils under investigation. The soils under study are fine textured and hence have high maximum water content but much is held at high suction. This is relatively higher from the upper member of the sequences (D.I, R.I and N.I) to lower members (D.III, R.III and R. III).

Available water capacity which is the numerical difference between the two parameters viz., field capacity and permanent wilting point for the soils under study are in the medium range

Table 37. Physical constants of the soil

(Diglipur sequence, Rangat sequence, Nicobar sequence).

Sequence	Soil series	Depth (cm)	Water holding capacity (%)	Moisture equivalent (%)
Diglipur	Diglipur upper series(D.I)	0-10.5	59.0	32.25
		10.5-37	56.31	33.02
		37-55	61.42	36.81
		55-150	62.10	37.43
	Diglipur Mid Series (D.II)	0-15	58.5	33.31
		15-45	58.9	35.01
		45-81	62.1	37.21
		81-150	63.2	38.31
	Diglipur valley series (D.III)	0-19.5	60.6	36.91
		19.5-40	61.53	37.01
		40-57	63.50	38.51
		57-150	64.81	39.32
Rangat	Rangat Upper series (R.I)	0-14	58.1	37.21
		14-43	57.32	37.82
		43-80	59.51	38.30
		80-150	61.55	39.52

Contd...

Table 37 (contd.)

Sequence	Soil series	Depth cm.	Water holding dapacity (%)	Moisture equivalent (%)
	Rangat Mid series(R.II)	0-17	59.82	37.32
		17-47	60.31	36.80
		47-80	62.50	38.10
		80-150	62.94	39.71
	Rangat Valley series(R.III)	0-19	61.31	36.61
		19-51	60.20	37.01
		51-78	62.41	38.21
		78-150	63.21	38.70
Nicobar	Nicobar upper series (N.I)	0-19	58.89	32.75
		19-59	59.73	34.25
		59-86	60.21	39.01
		86-150	61.10	37.51
	Nicobar mid series(N.II)	0-17	59.31	33.90
		17-48	59.72	34.81
		48-91	60.49	38.20
		91-150	61.51	38.51
	Nicobar valley series (N.III)	0-19	60.12	36.71
		19-59	60.34	37.08
		59-86	62.50	37.91
		86-150	63.17	38.50

as assessed on that basis of soil texture (Bryan, Davis, et al., 1972). Moisture equivalent is used as an indirect measure of wilting point (Bare, 1960). Moisture equivalent for the soils under study (Table 40) shows that they are in the medium range. An increasing tendency of the moisture equivalent is evident from the upper members of the sequence (D.I, R.I and N.I) to lower members (D.III, R.III and N. III) through the transition zone i.e. mid series (D.II, R.III and N.III) through the transition zone i.e. mid series (D.II, R.II and N.II). This finding is in consenance with available moisture capacity of the soil mentioned earlier.

Moisture retention is an important parameter of soil fertility. There are number of agroclimatological studies in which a substantial measure of statistical 'explanation' of variance in crop yields is achieved in terms of moisture stress alone (Hanna, 1974).

Moisture retention is equally important for both annual and perennial crops. For field crops which are annuals either season bound or time bound, high available moisture capacity has the effect of extending the growing season, since temperatures and radiation are often not limiting in the tropical climate of the Island. It is also a safeguard against the dry spells, during cropping season particularly soils D. III, R. III and N. III of valleys, which is of very common occurrence. Plantation crops and horticultural crops which are of perennial nature, good moisture retention limits yield loss caused by moisture stress and reduces the risk of crop loss during occasional long periods of dry spell. This is of much importance for soils of mid and upper slope members of the toposequence. In Andaman and Nicobar Islands where the scope for major irrigation schemes are very remote, moisture retention capacity of the soil is having added significance. There is only scope for minor irrigation schemes where economic use of water application is to be considered under intermittent surface flooding. This needs good moisture retention capacity with adequate permeability for planning of an irrigation programme. Mechanised cultivation was not very successful due to the sticky clay which prevents smooth running of the machines during the monsoon season.

Soil Erosion

Settlement of new areas are accompanied by a huge wastage of the natural resources with which nature originally endowed the land. Soil loss due to accelerated erosion is one of the natural corollaries of this human intervention with nature. The problem of soil erosion in these oceanic Islands under the dense forest cover commenced by the introduction of large number of families for settlement (Thampi, 1961, Thampi, 1962). It was observed that soil erosion was severe in the Islands. Erodability of the soils were studied for assessing the magnetitude of the problem of soil erosion in the Islands by the method suggested by Sen, A.T., Dutt, A.K. (1944). Soil loss and run offloss estimated at the sites of three toposequences are furnished in the Table 38.

Table 38. Erodability Indices of different soils and soil loss

Soil Series	Dispersion ratio	Erosion ratio	Soil loss Kg/ha.per inch of rain	Loss of run-off %	Slope percentage
Diglipur Upper Series (D I)	16.22	9.3	0.60	61.2	25
Diglipur Mid Series (D II)	16.51	9.41	0.51	46.72	10
Diglipur Valley Series (D III)	16.72	9.56	0.31	30.91	2
Rangat Upper Series (R I)	17.02	10.05	0.59	60.56	25
Rangat Mid Series (R II)	17.51	10.31	0.40	44.20	10
Rangat Valley Series (R III)	17.72	10.45	0.29	32.12	2
Nicobar Upper Series (N I)	17.61	10.01	0.54	62.44	25
Nicobar Mid Series (N II)	17.40	10.32	0.39	44.31	10
Nicobar Valley Series (N III)	18.20	10.62	0.21	31.41	2

Soil loss in all the soils are high and the rate of loss is directly proportional to the degree of slope and records highest for the upper slope members (D.I, R.I, N.I) with slope percentage 20. The lowest is recorded by the valley soil having 2 per cent slope. The run off loss is also simultaneously measured. The data provided in the table indicate run off loss is also high and maintains the toposequence from the upper members (D.I, R.I, N.I) which records the maximum run off loss. Besides many other environmental factors, soil type might also be one of the contributory factors for the high rate of soil and run off less. Minerology of the soil may also influence such properties as stability, state of soil aggregation and permeability of the soils. Soils with expanding clay minerals are more conducive to erosion than those with 1:1 lattice minerals under comparable conditions of physiography and vegetation (Biswas, T.D. and Karale, R. L., 1974). Dispersion ratio and erosion ration furnished in Table 39 for different soils also reflect the nature of the clay. Smith et al. (1953) have also reported high soil loss in similar soils. This may be due to the montmorillonite mineralogical content of the soil which swells up on wetting which reduced in filtration. This increases the rate of run off which in turn causes high rate of soil erosion. The high rate of soil loss is in agreement with the findings during the course of soil survey of the Island (Thampi, 1961).

In the light of the observations during soil surveys and implementation of soil conservation programmes it has been the experience that the soil of the Islands rapidly goes out of cultivation if adequate soil conservation measures are not taken up. The loss of top soil from the upper slope member to the lower slope member can be evident from the increasing tendency of top

Table 39. Fertility rating of the soils of the sequence Diglipur Sequence, Rangat Sequence, Nicobar Sequence

Sequences	Series	Depth (cm)	Av. nitrogen Kg/ha	Av. Phosphorus Kg/ha	Av.Potassium kg/ha	Rating: Av.Nitrogen	Rating: Av.Phosphorus	Rating: Av.Potassium
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Diglipur	DI	0-10.5	285	24.61	140.61	M	M	M
		10.5-37	208	20.21	151.21	L	L	M
		37-55	125	14.11	136.11	L	L	L
		55-150	130	11.21	130.00	L	L	L
	DII	0-15	310	30.51	150.21	M	M	M
		15-45	206	22.32	140.11	L	L	M
		45-81	116	15.22	125.05	L	L	L
		81-150	112	10.11	115.01	L	L	L
	DIII	0-19.5	290	28.23	140.91	M	M	M
		19.5-40	160	28.23	138.71	L	L	L
		40-57	105	13.12	127.21	L	L	L
		57-150	75	9.31	116.10	L	L	L
Rangat	RI	0-14	305	36.61	170.81	M	M	M
		14-43	245	30.52	142.61	L	M	M
		43-80	105	12.21	122.21	L	L	L
		80-150	90	10.12	110.10	L	L	L
	RII	0-17	345	34.21	178.90	M	M	M
		17-47	255	22.32	151.81	L	M	M
		47-80	110	10.00	140.21	L	L	M
		80-150	95	8.21	109.02	L	L	L

Table 39. (contd...)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rangat	RIII	0-19	265	32.31	185.03	L	M	M
		19-51	190	22.02	161.71	L	M	M
		51-78	115	13.21	130.21	L	L	L
		78-150	65	8.31	110.10	L	L	L
Nicobar	NI	0-14	410	34.81	165.01	M	M	M
		14-50	375	23.52	146.23	M	M	M
		50-79	125	13.41	131.31	L	L	L
		79-150	90	10.26	225.56	L	L	L
	NII	0-17	570	33.31	155.30	M	M	M
		17-48	465	22.25	139.51	M	M	M
		48-91	180	11.34	125.01	L	L	L
		91-150	90	8.2	111.20	L	L	L
	NIII	0-19	245	28.21	151.62	L	M	M
		19-59	350	32.31	134.32	M	M	M
		59-86	240	10.00	121.12	L	L	L
		86-150	125	9.00	132.01	L	L	L

L = Low M = Medium

soil depth from the upper members (D.I, R.I, N.I) to lower members (D.III, R.III, N.III).

In the light of the findings of the present investigation and the results obtained from field observations, following basic structures may be considered as soil conservation measures for the soils under investigation.

Soil series	Land capability class	Conservation measures
Diglipur upper series (D.I)	IV	
Rangat upper series (D.I)	IV	
Nicobar upper series (D.I)	IV	

Mechanical

1. Puerto Rico Terrace Mechanical-cum-vegetative method

Graded contour **trenches**with 0.5 percent longitudinal gradient and at a spacing of 1.25 metres vertical interval. Trenches with specification bottom width 30 cms, depth 30 cms. Vertical drains at a regular espacement of 60 metres. Filter Strips of different species of grasses viz., Panicum maximum, Penesitum Perpureum, Eragrastis Currula, Tripsicum laxum and Cmpapogan sp. may be grown on the upstream side of the trench as complementary practice to facilitate silting of soil material from the upstream side.

2. Graded narrow based bench terraces of inward slope constructed in staggered

Soil series	Land capability class	Conservation measures
		manner leaving the inter terraced area undisturbed. Terraces are to be connected to safe disposal drains. Risers of narrow terraces may be protected by grass sp. Cynadon dactylon, Paspalum notatum; legumes viz. Pueraria phaseoloides, Pueraria hirsuta, Centrosema Pubescens etc.
		Silt Traps. These may be constructed at the disposal end of trenches and terraces
		Cropping patterns For item one above (Puerto Rico terraces) horticultural crops like Mango, Jack, Citrus sp., Sapota, Guava, Tamerind etc. and plantation crops like Rubber, nutmeg, clove, cashewnut, red oil palm etc. may be grown as main crop.
		Inter crop Pineapple, Sweet potato, Castor, Turmeric, Mustard, Groundnut, Banana, Arhar, Yam, Jowar, Tapioca, Maize, Ginger, etc. may be grown as inter crop in the inter trenched area, whereas the areas with item no. 2 (narrow terraces) main crops may be grown

Soil series	Land capability class	Conservation measures
		in the terrace beds and inter crops can be grown in inter-terraced area. Agronomic Measures Safe disposal of excess run off may be ensured during monsoon and mulching, addition of organic matter in conjunction with chemical fertilizers N, P, K must be ensured to prevent the adverse effect of drought and to maintain productivity of the soil.
Diglipur mid series (D.II)	III	1. Bench Terracing Graded bench terraces with longitudinal slope of 0.5 percent (1 in 200) and inward gradient 2.5 percent, V.I interval 0.6 metre, length of terrace 60 metre may be constructed. Safe disposal drains and silt traps may be provided. This is recommended for these soils of Class III. In view of the present farming history of these Islands, economic considerations such as prohibitive cost involved in the construction, want of remunerative crops, marketing facilities, soil characteristics, construction of these structures may be done with caution andmay be used for growing
Rangat mid series(R.II)	III	
Nicobar mid series(N.II)	III	

Soil series	Land capability class	Conservation measures
		semiaquatic crops like paddy. Since the top soil is being removed adequate inputs are to be added. 2. Contour Bunding Graded bunds are laid out at a spacing of 0.5 metre vertical interval and with longitudinal gradient of 0.5 percent. Main bund section having 1.5 metre bottom width, 0.5 metre top width, 0.6 metre height may be constructed. Soils can be used for variety of crops mentioned above as inter crops and coconut, arecanut, citrus sp., coffee, cocoa etc. as main crop. Agronomic measures may be as in Class IV.
Diglipur valley series (D.III) Rangat valley series(R.III) Nicobar valley series(N.III)	II II II	Field Terracing with suitable safe diversion outlets are suggested. Bund specifications may be those suggested for Class III. These soils may be used for field crops with paddy as the main crop during kharif season followed by Pulses, oil seeds, vegetables, spices etc. Sugar-cane can also be grown. Addition of Organic matter and NPK must be ensured for desired results of crop production.

Soil fertility

Nutrients are present in the soil in available, unavailable and reserve forms. The process of weathering ensures continuous supply of nutrients for the maintenance of soil plant relationship.

Crop performance and yields are adversely affected by the deficiency in the supply of nutrients relative to the biological requirements of the plants. The principle of limiting factor is of great importance in the maintenance of soil fertility.

Fertility status of soils of the sequences are furnished in the Table 39.

Nitrogen is the major nutrient often deficient in the tropics. In the humid climates, lack of nitrogen is the greatest single cause of low crop yield, whilst even in semi arid climates, it may rank equally with shortage of water as a limiting factor (cf. Benninson and Evans, 1968). The data presented on the soils under study also reveal how status of nitrogen. The possible explanation may be that most of the soil nitrogen is derived from mineralization of organic matter, and the decline of organic matter status consequent upon the cultivation. Vegetation is burnt prior to cultivation. The available form of nitrogen (NO_3) is soluble and is leached under high rainfall condition. When the soil is subjected to drought during summer there is the prolonged drying which causes greater exposure of the surface to organic colloids; there follows a moisture induced population increase of nitrifying bacteria, which declines again as soon as the readily accessible organic surface decreases (Birch, 1960). There is a possibility of small upward movement of nitrate into the surface soil during dry season and downward movement to B horizon during rains, (Stephen 1962; Wild, 1972). The rate of downward leaching has been estimated as 0.2-0.3 cm per cm. of rain fall for soil nitrogen (Jones, 1975). The physical condition of the soil, the minerology i.e. montmorillonite dominance which accelerates rate run off, mostly undulating to rolling topography also removed the organic matter rapidly.

To maintain adequate supply of nitrogen addition of reasonable limits of organic matter, application nitrogenous fertilizer preferably in conjunction with manure or compost is necessary.

Phosphorus is present in soil in smaller quantity than nitrogen and is considered as a primary nutrient because it is essential for the plant growth. Phosphorus is frequently deficient in the humid tropics. Two problems of adequate supply are to maintain the supply of the soil solution preventing fixation. The soils under study are also low in phosphorus. The deficiency of phosphorus may be probably due to fixation.

Potassium is present in soils in larger quantities than phosphorus and less frequently deficient. Potassium status in the soils under study is medium to low. Primary supply, from weathering of feldspars and micas may be probably making a contribution to the potassium cycle.

From the discussion held it may be inferred that the soils are productive and fertility status may be ensured for better crop production together with adequate soil conservation measures as the soils are susceptible to high degree of erosive hazard within very short period.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

The present investigation is an attempt to study the morphological, physical, chemical and minerological characteristics of associated soils of land capability classes suitable for agriculture and occurring in toposequence, keeping in view the utilization aspect for the development of agriculture of Andaman and Nicobar Islands.

Three toposequences comprising a total of nine soil series, three each from Diglipur Sequence, Rangat Sequence and Nicobar Sequence were selected. Different soils occurring in each toposequence represent both the ends of the drainage scale from the upper slope to valley as well as land capability, class II to IV suitable for agriculture. The soils in each sequence change characteristically within a short distance.

1. The investigation of these soils show marked variation in their morphological characteristics. The dark reddish brown colour in the upper slope member of the sequence changes to light olive brown. There is a gradational change down the slope in texture from loam to clay, in structure granular to sub-angular blocky, in plasticity slightly to very plastic, in stickiness slightly to very sticky and acidity medium to slightly acid. The presence of graval in the upper and mid slopes changes to nil in the lower valley soil.

2. Ferric oxide as the dominant factor appears to give soil colour to the upper slope members (DI,RI,NI) whereas nature of clay, organic matter, moisture and presence of bases appear to influence the soil colour in valley soils (DIII,RIII and NIII).

3. The mechanical composition of the soils in a characteristic pattern follows the topographic sequence in which they occur. The texture varies from coarser to finer from upper to valley soil. The soils having relatively better drainage are subjected to vertical leaching with consequent eluviation of clay down the profile whereas profiles with impeded drainage is reflected with more or less uniform distribution of fine textured clay. Soil reaction is relatively higher in the upper members than valley members where drainage is restricted and also accumulation of water from upper region during monsoon season a natural phenomenon.

4. The chemical constituents of the soils show a similar pattern in relation to the topographic position of the soils. Silica increases down the slope and sesquioxide follows the reverse trend. The translocation of alumina in the upper slopes where drainage is relatively better is pronounced, whereas iron is minimum affected. Calcium and magnesium increase whereas titanium and potassium decrease down the slope. It appears that the drainage is the direct cause of the increased loss of Silica, alumina and calcium from the upper slope member as compared to the poorly drained ones. Carbon, Nitrogen

ratios shows a trend of narrowing down the profile as the drainage becomes poorer.

5. Chemical composition of the clay fractions show certain variations in different constituents. Silica content shows an increasing tendency whereas the sesquoxide decreases along the slope. Calcium and magnesium are present in greater proportion in poorly drained soils. Silica-sesquioxide ratio increases as the drainage becomes poorer. The upper slope members indicate more alteration in the clay fraction.

6. Manganese content of the soil is relatively high. The mobility of the manganese is greatly influenced by the soil reaction, texture, structure and drainage conditions. There is an increasing trend in manganese in upper slope members down the profile but lower members show a relatively uniform trend.

7. The soils in the sequence exhibit high cation exchange capacity and also an increasing trend down the slope. Eluviation of clay is reflected in their cation exchange capacity. Exchange complex is relatively less saturated in the upper slope members, but under impeded drainage it presents higher degree of saturation. Calcium and magnesium forms the dominant position the exchange complex. Exchangeable sodium and exchangeable potassium are a low

and show increasing trend down the slope. Relatively high content of magnesism is in conformity with the montmorillonite clay.

8. pH of the soils appears to be relatively low in comparison with high base saturation. May be due to high content of Magnesium in the exchange complex.

9. The cation exchange capacity of the clay fractions is high and increases down the slope. This indicates the nature of the clay mineral and the gradational change it undergoes from the upper member to the lower member of the drainage scale.

10. Minerological composition of the fine sand fraction does not show any marked variation. They differ rather distinctly in their relative proposition. The quartz and orthoclase feldspars are the major constituents of light minerals. Orthoclase feldspars of the higher alope members are mostly altered, but the alteration diminishes as the drainage becomes poorer. Resistant minerals like magnatite,zircon and tourmaline persist throughout the sequence. The absence of weatherable minerals indicates that the soils are formed from the pre-weathered rock rather than from the original rock material.

11. Clay minerals constitutes montmorillonite in association with illite and kaolinite. Montrmorillonite forms the major and others are in traces. All the minerals are in a

state of poor crystallinity indicating immaturity of the soil forming process. The crystallinity of montmorillonite appears to be relatively better formed in the lower slope member than the upper slope member. Changes of minerological composition within the prifile are not significant. Silica-sesquioxide ratio and high base saturation are closely associated with the identified montmorillonite type of clay.

12. From the result obtained on the morphological, physical, chemical and minerological characteristics of the soils associated in the sequence, it can be inferred that the development of soils have taken place on more or less uniform parent material and similar environmental conditions of this oceanic region. But the major differences in these soils are in their properties which are primarily influenced by the moisture regime prevailing in different locations of the toposequence. These soils occurring in different situations of the sequences are also in the characteristic pattern as conceived in the definition of the catena.

13. The soils have been classified under USDA 7th Approximation system and all the soils fall within the order Alfisol. This is clearly characterised by the argillic horizon. Upper slope and mid slope members come within sub-order Udalf and lower members Aqualfs. In the Great Group level all the upper slope members of the sequence and mid slope members fall within Hapludalfs except Nicobar upper series NI which

is Paleudalfs. Sub group level show mollic hapludalf for Diglipur and Rangat Upper series and other soils of upper series come within Typic Hapludalfs and Nicobar Upper series forms typic Paleudalfs. The lower members fall within Typic Ochraqualfs. In the family level the soils come under 'Fine Clayey mixed hyper thermic.' The classification in general maintains the toposequence and uniformity indicating the earlier findings of the similarity of soils in the same situations of toposequence.

14. The findings have revealed similar characteristics of soils occurring in same land capability classes, II, III and IV. Capability classes II corresponds to Valley Soils D III, R III and N III. Same is the case with that of land capability classes III which is associated with soils of mid slope D II, R II and N II and Class IV with D I, R I and N I.

15. The information obtained is valuable for the interpretation of aerial photographs, remote sensing imageries, toposheets for delineating different types of soil units in association or otherwise for the preparation of soil maps. The utility is further enhanced to make better evaluation of the types of lands, their nature, extend and prospect of development could be done with rapidity in the remote locations of the xxx Island.

16. The results obtained from various studies also facilitate proper land use planning to enhance productivity of the land and to maintain sustained yield.

17. Fertility study of the soils of the sequence give indicative results of NPK which reveal Nitrogen Medium and Phosphorus Low in status and potash in the medium range.

18. Studies on moisture regime also reveal that the moisture holding capacity is high and available moisture capacity is medium. Moisture conservation measures need be considered. Soils of Valley lands retain the residual moisture for longer periods. This can be profitably utilised for second crop after paddy.

19. Reduction in the available moisture capacity and water holding capacity in the upper and mid slope members of the catena call for moisture conservation measures like mulching to prevent the crops horticulture/plantation from moisture stress during summer months.

20. In the light of the moisture regime that is gradually diminishing from lower member of the profile to upper member it may be advisable to design the cropping pattern keeping in view, more moisture loving plants may be planted in soils of mid slope and down below up to the valley viz., Coconut, Arecanut, Citrus, etc. Other more drought tolerant plants like mango, jack, sapota etc. on the upper slope capability class (IV). Lower slope member D.III, B.III and N.III may be utilised for growing semi aquatic crops like paddy followed by rabi crops viz., oil seeds, pulses, sugarcane, etc.

21. The soils are highly susceptible to erosion, soil loss and water loss are progressively increasing from lower member of the sequence to upper member. Appropriate soil conservation measures viz., mechanical, agronomic and vegetative are pre-requisite to putting the land under plough.

22. The data reveal run off loss is very high due to various factors as discussed earlier. Water harvesting structures may be constructed to ensure the use of available water resource during monsoon to save the crops from the damage at times of dry spell during cropping season.

23. Since scope for major irrigation schemes are very meagre emphasis may be made for minor irrigation schemes.

24. Scope for mechanization of Agriculture is very limited due to the sticky montmorillonitic type of clay which prevent smooth working of power tillers and tractors during monsoon.

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ANNEXURE I. **CLIMATOLOGICAL TABLE**

Station Port Blair LAT. 11° 40' N. LONG 92° 43' HEIGHT ABOVE M.S.L.79 METRES. BASED ON OBSERVATIONS FROM 1931 TO 1960 Mateorological Deptt.

MONTH	AIR TEMPERATURE								HUMIDITY		RAINFALL		MEAN WIND SPEED.
	MEAN (OF)				EXTREMES								
	DAILY MAX.	DAILY MIN.	HGT. mnth.	Lwt. mnth.	HIGT.	Dt. & YEAR	Lwt.	Dt. & Yr.	Relative Humidity.	Vapour Pressure	MONTHLY TOTAL	No. OF RAINY DAYS	
JANUARY	29.2	22.7	30.7	22.0	32.2	24 1960	16.7	23 1940	70 77	26.1 25.5	28.9	2.1	13.4
FEBRUARY	29.8	21.8	31.5	19.5	32.8	22 1896	17.2	11 1949	71 76	26.1 25.8	26.3	1.7	9.5
MARCH	31.1	22.5	33.1	20.7	35.1	19 1958	17.8	12 1949	69 74	27.3 26.0	22.5	1.8	8.0
APRIL	31.9	24.2	33.8	22.8	36.1	28 1889	19.4	13 1922	70 77	30.4 29.1	71.2	5.9	8.7
MAY	30.9	24.4	33.4	22.8	36.1	8 1889	18.9	29 1935	77 84	31.0 30.4	362.5	15.1	12.1
JUNE	29.1	24.2	31.1	22.3	35.6	16 1933	19.4	22 1939	83 88	30.6 30.5	589.5	23.5	19.8
JULY	28.9	24.1	30.7	22.1	32.8	20 1941	18.3	10 1941	84 88	30.6 30.3	435.5	20.5	19.9
AUGUST	28.8	24.1	30.4	22.6	31.7	5days 1932	20.6	3 1914	84 88	30.4 30.2	435.9	22.5	18.9
SEPTEMBER	28.7	23.6	30.6	22.3	31.7	10 1888	20.0	16 1890	84 89	30.2 29.6	516.2	20.4	15.9
OCTOBER	29.0	23.6	31.0	22.6	35.6	23 1906	17.8	27 1912	81 89	30.3 29.3	329.2	16.6	10.7
NOVEMBER	29.2	23.6	30.9	22.1	31.7	5 1907	19.4	18 1891	76 85	29.3 27.8	205.4	11.1	11.7
DECEMBER	29.0	23.1	30.5	20.4	32.2	30 1896	18.3	26 1907	72 80	27.0 26.2	157.4	6.4	13.9

ANNEXURE II

Land Utilisation Statistics

(In hectares)

Classification of reporting area	1976-68	1968-69 (Provisional)
Total geographical area	829,263	829,263
Total reporting area	42,239	42,596
Area not available for cultivation	3,304	3,070
Other uncultivated land excluding fallow land.	27,040	27,207
Fallow land	1,410	1,549
Total cropped area	10,633	11,059
Net area sown	10,486	10,770
Area sown more than once	10,147	289

ANNEXURE III.

Area, Population and Density

I t e m	P a r t i c u l a r s
Area (In sq.kilometres)	8,293
Population (1971)	115,090
Density per square kilometre (1971)	14
Number of towns	1
Population of Port Blair (1971)	26,212
Females per 1,000 males	644

ANNEXURE - IV

General types of conservation practices and uses recommended for land capability classes

LAND SUITABLE FOR CULTIVATION

Land Capability Class (1)	Subclass (Dominant kind of land) (2)	Suitable for (Only the most intensive safe use is mentioned) (3)	Special needs or precautions (4)
I. Very good cultivable land. (light green on map).	Deep, nearly level productive valley land.	Intensive cultivation to all climatically adapted crops.	No special difficulty in farming. Usual good farming practices to maintain soil fertility and conserve water.
II. Good cultivable land. (yellow on map).	IIc-Good soil on gentle slopes subject to water erosion or wind erosion on sandy soils.	Cultivation with precaution.	Protection from erosion. Use conservation irrigation methods.
	IIw-Good soil, slightly wet or subject to overflow.	Cultivation with management of excess water and selection of crops adapted to wet condition.	Drainage improvement or flood protection.
	IIs-Soil with minor soil problems such as clay or sandy texture, moderate depth, or slight alkali.	Cultivation with selection of crops adapted to soil limitations.	Treatments to offset soil limitations and to conserve irrigation water.
III. Moderately good cultivable land (red on map).	IIIe-Good soil on moderate slopes subject to water erosion, or sandy soil subject to wind erosion	Cultivations with precautions against permanent land damage.	Special attention to erosion control and conservation irrigati

Contd.....

ANNEXURE IV (contd.)

(1)	(2)	(3)	(4)
	IIIw-Good soil, moderately wet or subject to overflow.	Cultivation with careful management of excess water and selection of crops adapted to wet conditions	Intensive drainage, improvement or protection from flooding.
	IIIs-Soil moderate problems due to moderate depth, graveis, or alkali.	Cultivation with careful selection of crops adapted to soil limitations	Intensive treatment to offset or overcome soil limitations and conserve irrigation water.
IV. Fairly good land, Suited for occasional or limited cultivation.(blue on map).	IVe-Moderately steep land subject to serious water erosion or sandy soils subject to wind erosion.	Occasional cultivation in rotation with hay or pasture, or orchards protected by permanent cover crops.	Intensive erosion control when in cultivation.
	IVw-Bottom land that is very wet or subject to severe overflow.	Cultivation to special summer crops,hazard of crop failure is always present.	Intensive drainage,Special attention to seeding and harvest dates to minimise crop failure on overflow land.
	IVs-Fairly good land with limitations due to shallowness,gravel,stone, or strong alkali.	Occasional cultivation in rotation with hay or pasture.	Very intensive treatment to overcome soil limitations. Careful selection of crops.
	IVc-Good soil with just enough rainfall or crops in favourable years.	Cultivation during wet years,frequent crop failure.Better in permanent vegetation.	Conserve all rainfall-develop water for irrigation or convert to pasture or grazing use.

ANNEXURE V.

LAND CHARACTERISTICS IN RELATION TO LAND CAPABILITY CLASS

Characteristics	Limitations	General types of Lands	Land Capability Class
1. Level land with deep, well drained soil of satisfactory texture and structure, free from harmful factors like excessive lime, acidity, alkalinity or salts; fit for a variety of crops; responsive to manuring. The soil texture in these cases usually may range from fine sandy loam to loam or silty loam and well furnished with soil organic matter and plant nutrients. These soils have capacity to maintain physiological availability of water.	Few or no limitation of soil depth, erosion, water table, sub-soil barrier overflow or wetness etc.	Fertile, high yielding alluvial lands. Lands naturally occurring on level terrain on high river banks and those with similar characters with facilities for irrigation.	Normally Class I land. This Class will go up higher with the effect of environmental and other limitations.
2. Gently to moderately sloping and with deep soil of fairly satisfacture texture and structure; subject to occasional overflow or wetness easily correctible; slightly affected by salinity and such harmful factors. Moderately susceptible to erosion or slightly to moderately eroded.	A) Susceptible to moderate erosion. B) Slight drainage impedence. C) Slight marshiness. D). Droughtiness.	1) Rainfed lands for dry and wet crops in Red and Black soil regions. 2) Medium to heavy textured soils of shallow valleys in moderate rainfall regions.	Class II lands. Erosion hazard will need classification as IIe, root zone limitation as IIs and drainage difficulties as 11w.

ANNEXURE V.(Contd.)

	Characteristics	Limitations	General types of Lands	Land capability class
	Sandy loam to loamy soil overlying heavier subsoil, with moderate permeability and drainage.	E) Moderate condition of salinity and acidity slightly affecting crops.	3) Medium to heavy textured soils under bunds on gently to moderately sloping terrain.	
		F) Nutrient reserve poor.		
	Fine sandy laom to loamy soil overlying sand or gravel, deep soil but rapidly permeable.		4) Bottom lands subject to occasional overflow easily correctible.	
	Silty laom to loam on -clay or silty clay, moderately deep, slowly permeable.		5) Foot hill soil quite deep, overlying porous substrata of sand or boulders.	
3.	Gently to moderately to strongly sloping lands to moderately deep soil of satisfactory texture, subject to frequent overflow or wetness, presence of harmful factors including salinity or alkali, high water table etc. Moderately affecting crop growth. Soils of heavy ~~tex~~ texture subject to severe erosion hazards or having adverse effects of past erosion.	A) Very susceptible to erosion. B) Drainage impedence rather marked. C) Marshiness. D) Droughtiness and root zone limitation marked.	1) Heavy textured soil of expanding type clay mineral with gentle slopein black or mixed Red and Black soil Regions. 2) Soils with subsoil barrier in the alluvial, Red or Black soil Regions.	Class III land. Erosion hazard or past erosion will need classification as IIIe, root zone limitation as IIIs, drainage difficulty as IIIw.

ANNEXURE V.(Contd.)

Characteristics	Limitations	General types of Lands	Land capability class
	E) Salinity and alkali hazards.	3) Lands in alluvial or Black soil Region with higher water table, affected by salinity or alkali that reduce crop yield.	
Coarse to medium texture soil moderately deep underlain by sand or gravel.	F) Nutrient reserve poor.		
	G) Poor moisture holding capacity.		
Silt laom to loam, poorly drained moderately permeable over very slowly permeable sub-strata (Clay pan, Fragipan etc.).		4) Bottom lands than remain wet or are subject to frequent overflow.	
		5) Bunded lands on moderate to strong slopes in the Red and Laterite Soils.	
		6) Terraced land for paddy cultivation in strong slopes in the hilly and mountainous region with moderate rainfall.	
4. Strongly sloping to steep land, deep to shallow soil, favourable texture, soils severely affected by salinity or alkali permitting only salt telerant crops to grow. Soil under severe erosion; sandy or concretionary soil with very low moisture holding capacity. Highly saline organic soils.	A) Severe past erosion.	1) Concretionary soil of the nature of Bhata soils of M.P. or Dabba soils of A.P.	Class IV land. Erosion needs classification as IVe, root zone limitation as IVs, Wetness as IVw.
	B) Severe root zone limitation.		
	C) Pronounced marshiness.		
	D) Bad droughtiness.	2) Coastal alluvium(Sandy) or sandy deposits on river banks, other sandy stretches as in cultivated fields.	

ANNEXURE V.(Contd.)

Chatacteristics	Limitations	General types of Lands	Land capability Class
Gravelly or concretionary soil overlying gravelly or concretionary subsoil, rapidly well drained. Sand to loamy sand overlying sand or coarse material, well drained, rapidly permeable.	E) Strong salinity or alakali hazard.	3) Sandy soils of arid and semi-arid regions. 4) Alluvial or Black soils of semi-arid regions severely affected by salinity or alkali. 5) Kari(Saline Peaty)soils. 6) Terraced paddy lands on steep slopes. 7) Bunded lands with stone revetments on steep slopes.	
5. Level or nearly level land with stony or rocky soil, marshy soils etc.	A) Cultivating implements cannot be worked. B) Crop management practices cannot be applied.	Lithosolic soils of central India; Marshy lands. Stony or rocky lands. Bottom lands along stream banks, subject to frequent flooding.	
6. Steep to very steep land with deep to shallow soil, shallow to very shallow soils on gentle to steep slopes, soils with severe erosion hazard or very severe past erosion. Soils with extreme salinity and alkali hazards, soil under severe climatic restrictions.	A) Very rapid runoff attaining high velocity causing deep cutting. B) Stoniness and erosion condition hindering cultivation of arable crops by application of usual management practices. C) Low moisture holding capacity and nutrient reserve. D) Severe salinity of alkali hazard.	1) Steeply or very steeply sloping lands of the hilly and mountainous regions with deep to shallow soils. 2) Severely eroded lands of Red and Black soils or other soil groups. 3) Very shallow soils with concretions, kankar or stones on the surface. 4) Desert sands and dsan dunes.	Class VI lands, wit[illegible] increasing severit[illegible] of the hazards, th[illegible] lands are to be gr[illegible]uped as Class VII.

ANNEXURE V.(Contd.)

Characteristics	Limitation	General Type of Lands	Land capability Class
		5) Coastal sand dunes	
		6) Lands severely affected by salinity or alkali.	
		7) Lands subject to acute marshiness, including coastal mangroves.	
7. Bad lands, rock cut crops etc.	A) Severe root limitations.	1) Rocky escarpments.	Class VIII
		2) Cherty and very stony ground with shallow soil interespersed with sheet rock.	