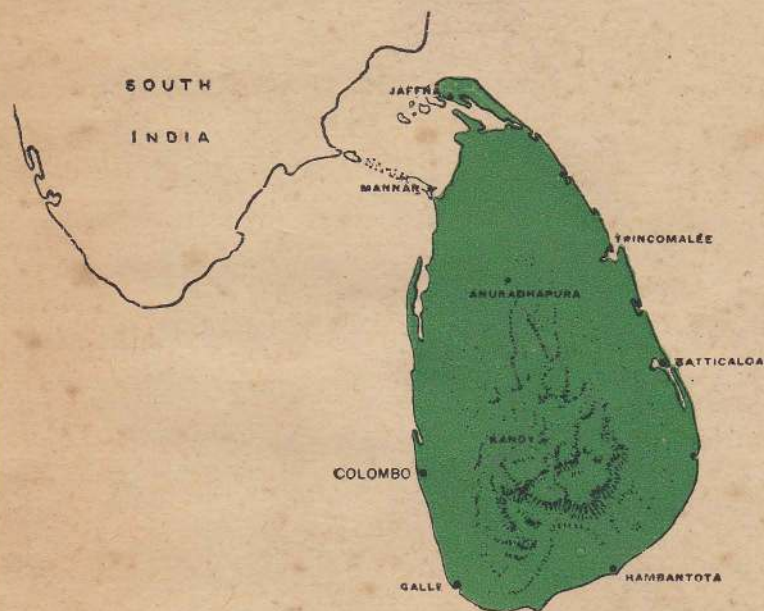


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# Bulletin of the Ceylon Geographical Society

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July—December, 1954

## STRUCTURAL TRENDS IN THE CENTRAL HIGHLANDS OF CEYLON\*

By P. G. COORAY

### ABSTRACT

A map of the Central Highlands of Ceylon showing the main structural trends is exhibited. The map shows that there is a dominant NNW—SSE trend (*viz.* the Taprobanian of Coomaraswamy) which varies to NW—SE and even to WNW—ESE. There is also a subordinate NNE—SSW trend.

The main axes of folding are indicated, and the nature of both major and minor folds, as well as of other structures is discussed.

### INTRODUCTION

The map which is exhibited as the main part of this paper covers the area included in the following one-inch topographical sheets:—

Kandy	Hanguranketa
Hatton	Nuwara Eliya
Ratnapura	Haputale

As such it includes most of the region known as the Central Highlands of Ceylon, but does not include the Rakwana Hills on the SW, the Matala Hills on the north, and the Knuckles Range to the north-east. On this map have been plotted all the known dips and strikes of foliation and bedding planes as recorded in the field maps of the Department of Mineralogy. It should however be made clear that while some of these readings have been accurately determined many of them are only estimated. On the basis of these several hundred readings, the major trends lines of apparent folds have been drawn, and in many cases these have been checked in the field.

While therefore it may appear that some of the trend lines are hypothetical and that the map itself is premature, no finality is claimed for this map, as indeed it is claimed for no geological map, and it is submitted as a preliminary report on work done. We feel however that no apology is needed in view of the fact that so many before us have talked glibly of various structural trends in Ceylon but no one has hitherto attempted to show us these trends by any demonstrable means.

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\* Paper read before Section D, Ceylon Association, for the Advancement of Science  
10th Annual Sessions, 1954.

## STRUCTURAL TRENDS

It was in 1906 that the first bit of detailed geological mapping was done when Coomaraswamy worked out the geology and structure of the Kandy District. He showed that there was a set of NNW-SSE trending folds, the axes of which dip to the NW, and he named the movements which gave rise to these folds the TAPROBANIAN FOLDING.

If the map exhibited today shows anything, it is that this NNW-SSE or NW-SE trend of fold axes is dominant over most of the Central Highlands of Ceylon. It is therefore more in keeping with the principles of nomenclature to call this the Taprobanian trend, as indeed Wadia 1943 did, and not the Wijayan trend as Kularatnam 1954 mistakenly has done.

We proceed to examine these folds in a little more detail.

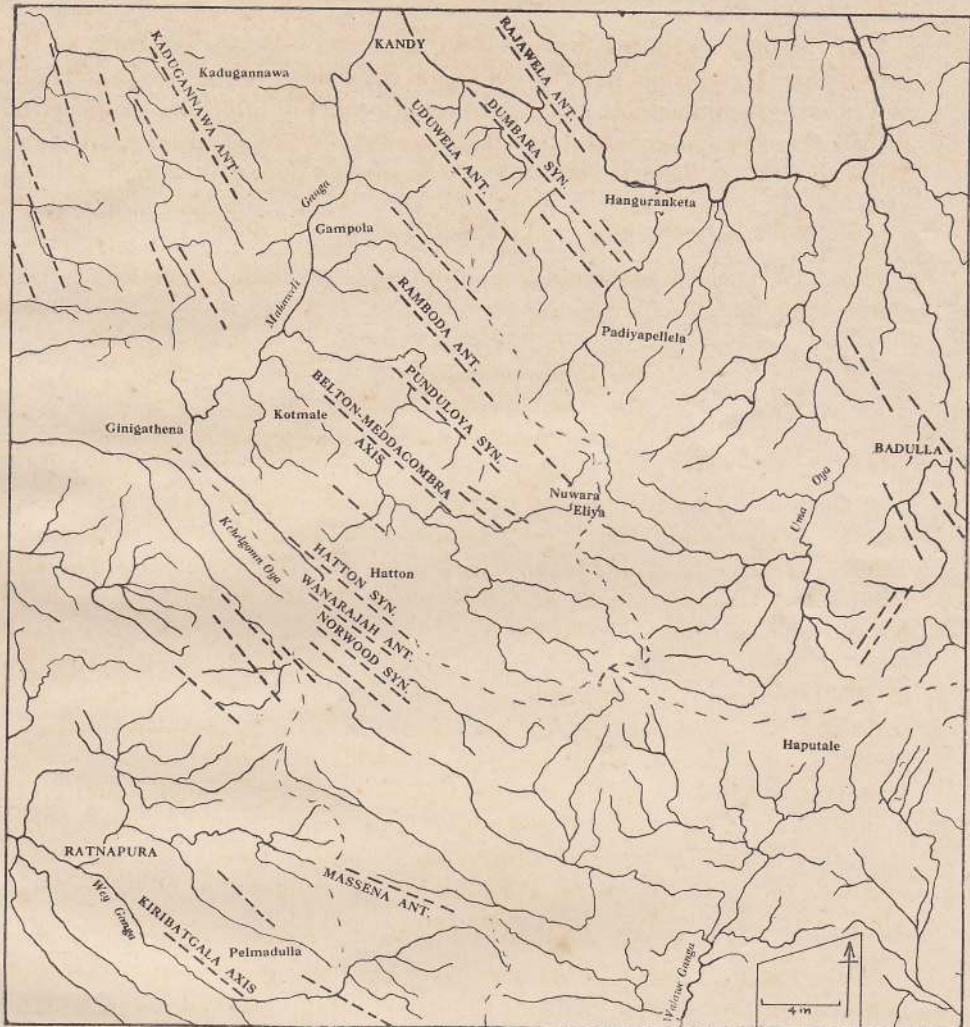
A. Perhaps the best known group of folds are those of the Kandy District, the most prominent of which are—

the Rajawela anticline,  
the Dumbara syncline,  
the Uduwela anticline, (all described by Coomaraswamy).

There are in addition several minor folds, unnamed but recorded by Coomaraswamy, Wadia and others, for example near Padiyapellela, Haragama, and Teldeniya. This area should be regarded as the type locality for Taprobanian folding and trend direction; the close nature of the folding, the predominant NNW-SSE to NW-SE direction of the folds, and the north-westerly pitch of the fold axes are all evident. Coomaraswamy also pointed out a feature of the Dumbara syncline which we begin to think is more significant than he realised. He showed that at the apex of the fold the apparently single band of limestone must consist of an isoclinal overfold, overturned towards the ENE. It is now a well-known fact that beyond demonstrable synclines and anticlines in other parts of the Central Highlands the dips frequently are in a single direction. It is therefore suggested that open folds frequently pass along the strike into overfolds owing to the lateral variations in the composition of the beds, a fact which consequently affects their competency.

B. The next group of folds to be noticed are those of the Hatton Sheet, first described by Adams 1926. If the strike and dip readings are to be believed, the following fold axes should be recognized :—

the Ramboda anticline  
the Punduluoya syncline  
the Belton Meddacombrā axis  
the Hatton syncline  
the Wanarajah anticline  
the Norwood syncline and anticline  
the Maskeliya folds  
the Radella anticline and syncline



MAP OF STRUCTURAL TRENDS IN THE  
CENTRAL HIGHLANDS OF CEYLON

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According to both Adams and Sirimanne (1954), the most north-easterly of these consists of a gently folded series of anticlines and synclines. The northerly pitch of the axes is not so apparent here except in the case of the Ramboda anticline. In fact, several of the minor folds seem to pitch in the opposite direction, *e.g.* the Radella folds, and in the Hatton area there is little, if any, pitch at all. The strikes of most of these axes is more NW-SE than NNW-SSE, and they appear to continue north-westwards into the region to be described below.

C. The group of folds between Kadugannawa and Kegalle can be seen to have a more NNW-SSE strike than those mentioned above. The best known of the group is the Kadugannawa anticline first mentioned by Coates 1935, while a fairly broad syncline is to be found east of the Maha Oya valley. In this region too some of the axes appear to pitch to the SE.

D. The Ratnapura-Balangoda region in the south-west corner of the map has a predominantly WNW-ESE trend. The Kiribathgala syncline east of Ratnapura is the most noticeable, whereas near Balangoda is a group of rather complicated folds, of which the Massena axis is the only one shown. Rodding, lineations and minor folds indicate the presence of a major system here, but detailed mapping is required before anything more can be said about them, except that south-eastwards, in the vicinity of Balangoda itself, these folds seem to pass into a system of close, isoclinal and overturned folding.

E. On the eastern edge of the map are the trends of the Badulla District, and it is seen that these are also in a NNW-SSE direction. The main axes here are—

the Badulla syncline  
the Ledgerwatte folds  
the Hali-Ela group  
the Demodera group

F. The north-eastern portion of the map has so far not been covered by reconnaissance mapping so we are unaware yet of trend directions of folds. It is however significant that not only does the drainage pattern follow a NNE-SSW direction but also that the strike of the hills north of the Mahaweli Ganga elbow bend is conspicuously N-S and comes up against the Taprobanian trend of the Kandy District.

G. Finally to be considered is the Uva Basin, with Welimada almost in the centre of it. According to Parsons (1907) "the western portion of Upper Uva is covered by a well-marked anticline," but we are unable to agree with this statement. In fact, one of the notable features of the map is the striking contrast between the Uva Basin and the other regions mentioned, *e.g.* the Hatton Area. The former is conspicuous by the absence of any dominant trend lines in it. What is evident is that there are at least two major structural directions as reflected in the minor folds present and in the lineations. The rocks of the Uva Basin, are characterised by widespread puckering and contortion of the foliation planes, and minor folds and faults and thrusts are common in them (Fig. 1). Moreover, the changes of dip and strike are so frequent as to be explained on the assumption

either of several fold systems or of multiple faulting. In any case we are driven to the conclusion that this area has had a somewhat different tectonic history to the rest of the Central Highlands.

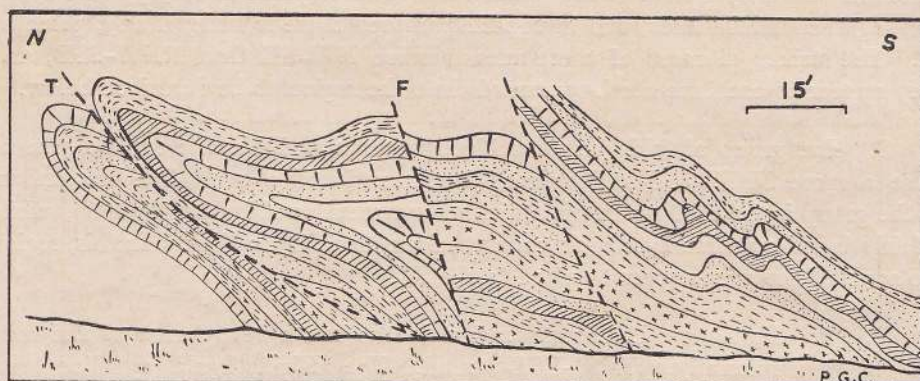


Fig. 1.—Recumbent fold, thrusts and puckering of strata in Uva Basin.  
Loc : Bindunuwewa Farm Road, Bandarawela.

H. In his paper on the Kandy District, Coomaraswamy suspected that the axes of the folds pitch on both directions, and that there was a system of folding at right angles to the Taprobanian system. To these he gave the name of Vijayan movements. Wadia however, in 1943, expressed the opinion that Coomaraswamy's Vijayan or NE-SW trend was not a separate fold system, but only a variant of the major structural direction of Ceylon. This was in accordance with his concept of a centrally situated synclorium into which the Khondalite rocks are supposedly folded. While we are not in a position at present to dispute the concept of a synclorium and while we may accept the veering of the strike lines near Trincomalee towards the NE or NNE as variations of the Taprobanian system, we are obliged to disagree with Wadia that only one orogenic movement has affected the rocks of the Central Highlands. Minor folds trending NE-SW the south-easterly pitch of some of the Taprobanian fold axes, the frequent occurrence of small-scale domes and what appear to be basin-shaped structures, overfolding towards a south-easterly direction—all these tend to indicate that Coomaraswamy may have been right in suggesting a subsidiary movement giving rise to NE-SW or Vijayan trend lines.

#### NATURE OF THE FOLDING

We have so far been considering mainly the directions in which the main structural lines trend. We now look more closely at some of the types of folds to be met with in the Central Highlands whose axes gives us these structural trends.

A. **Open Folds.**—These can be seen in nearly all areas and vary from a few feet to a few miles across. The best known of them is the Ramboda anticline, described by Adams as "low anticlinal fold" along the axis of which a tributary of the Kotmale Oya has eroded a wide valley in which low hills or erosion remnants

can be seen being rapidly destroyed by the torrents which rush through the valley during the heavy rains. The rocks on either side of the valley rise a couple of thousand feet in high precipices displaying the basset edges of a gneissose series of rocks, whose foliation dips away from the valley on either side at 10 to 25 degrees (Fig. 2). The best view of the anticline is obtained from Ramboda itself.

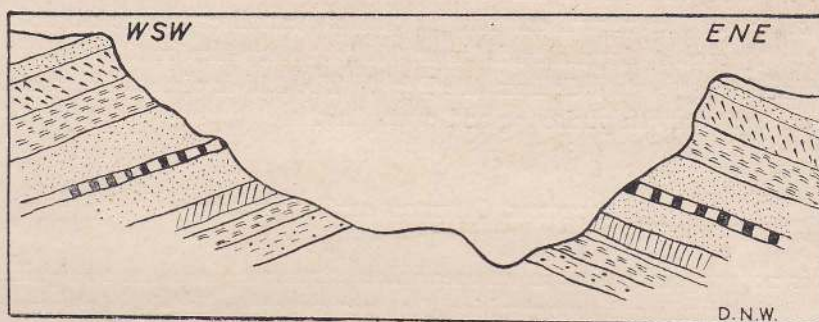


Fig. 2.—Diagrammatic sketch of Ramboda axis of folding; looking northwards from Ramboda. (after D. N. Wadia).

**B. Inclined Folds.**—Inclined folds or overfolds, are those in which the axial plane is off the vertical. They can be seen in several localities especially when on a small scale (Figs. 3 and 4). They are important elements since failure to recognize such folds may lead to faulty interpretations of structure.

**C. Isoclinal Folds.**—In these the two limbs dip at equal angles in the same direction. They may be vertical or inclined.

**D. Recumbent Folds.**—A recumbent fold is one in which the axial plane is nearly horizontal.

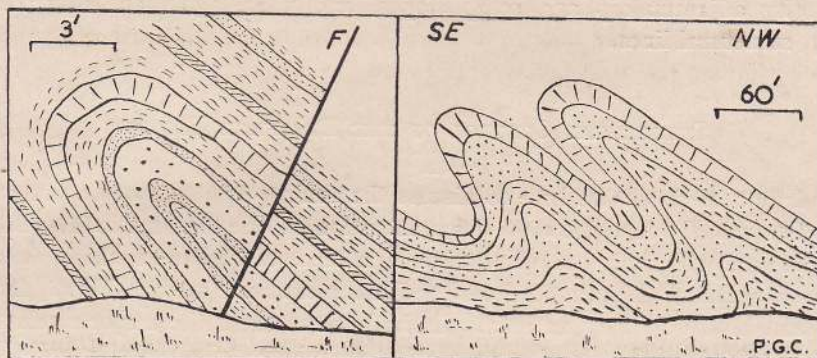


Fig. 3.—Overturned fold with fault.  
Loc: Culvert 11/4, Balangoda—  
Kaltota road.

Fig. 4.—Inclined isoclinal folds.  
Loc: Culvert 17/8, Balangoda—  
Kaltota road.

Recent detailed mapping is making it clear that overturned and recumbent folds are much more common in the Central Highlands than was formerly suspected. The two best known examples are those seen by Wadia and described by him in his field note books.

A recumbent fold near Devon Falls, Dimbulla Hills, can be seen from the P.W.D. District Office, near the elbow bend on the road between Dimbulla and Talawakelle; another recumbent fold in quartz granulites in the Adam's Peak region can be seen at Appalakanda, in an 800 foot scarp-face on the north bank of the stream flowing eastwards from the Peak. The fold is almost horizontal and the laminae show much puckering and crumpling.

### STRUCTURAL CONTROL OF TOPOGRAPHY

It is not surprising that in an area where structural lines are so significantly displayed the significant topographical features are controlled by the same structural lines. Much of the physical features of the Central Highlands are composed essentially of long parallel ridges and valleys and these are a reflection of the parallel folds which have been shown to exist. For example—

- (a) Valleys may be either anticlinal or synclinal, Ramboda being an example of the former, the Laggal Oya illustrates the latter. Coomaraswamy has also described an almost perfect synclinal valley at Munwatte, south of Hanguranketa ;
- (b) Anticlinal scarp ridges like the Kaipoogalla-Great Western scarp, the Peacock-Moneragala ridge and the Alagalla scarp are prominent and spectacular features of the topography of the Highlands, and in most cases they follow important axial trends ;
- (c) Parallel strike valleys and ridges, one of the commonest physiographical features of the region, especially in the Sabaragamuwa area are formed by adjacent dip and scarp slopes, and these again are controlled by structural lines.

### STRUCTURAL CONTROL OF THE DRAINAGE PATTERN

It is not the intention here to discuss the drainage pattern of Ceylon or even of the Central Highlands, but to draw attention to one element in it. This can best be done by showing you the drainage patterns of two areas which have been selected at random. The first is from the Hatton area, the second (Fig. 5) from the south-west of the Ratnapura area. In both these areas the major streams flow in a NW-SE direction, and many of the minor tributaries parallel these major streams. This is to be expected at a glance as the map will show that since the dominant trend lines are in this direction the valleys will normally be in the same direction.

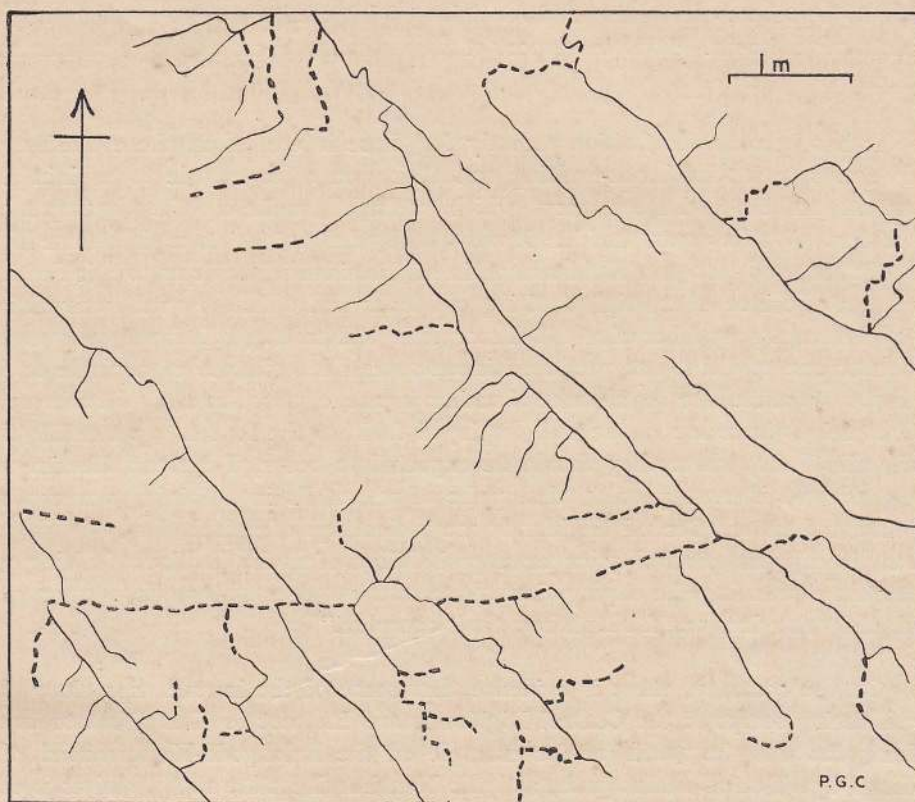


Fig. 5.—Drainage pattern of part of the south-west portion of the Ratnapura one-inch topographical sheet.

What is more interesting is the direction of some of the tributaries. These fall into 3 main groups, *viz.* N-S, NE-SW, and E-W. Of the NE-SW group it can perhaps rightly be said that these are consequents and obsequents, or to be less technical, streams which find the shortest way down the dip and scarp slopes of the valley into the main stream. The other two groups however cannot be explained in this manner. It is well known however that in an orogenic belt there are 3 major sets of joints all directly related to the directions of the compressional force and to the internal stresses and strains set up by these. They are called cross and oblique joints. It is suggested here that the N-S and E-W tributaries are structurally controlled streams flowing along major joint directions, the joints forming a conjugate system of oblique joints. In fact while some of the NE-SW streams might also be controlled by dip or cross joints, some portions of the main streams certainly are.

#### CONCLUSION

We have seen that within the Central Highlands while the predominant structural trend is a NW-SE one (varying from NNW-SSE to WNW-ESE), a subordinate NNE-SSW or N-S direction is also present and may very well belong to an earlier or later orogenic period. We have also seen that while open

folds are common, overfolding and recumbent folds are important elements in the structural make-up. It is in respect of these that our concluding remarks are made.

It has become the fashion recently for those interested in the evolution of land forms to invoke block-faulting and tilting on a large scale to explain the near-flat surfaces and steep-scarps which so largely make up the physiography of Ceylon. Wadia began the idea, it was used by Leiter 1947 to explain some high level basins, and last year Kularatnam, in his Presidential Address to this Section extended the idea of multiple faulting of blocks and splinters with some tilting to explain a large number of so-called morphological units. It is strange, however, that not one of them has produced incontrovertible evidence of a single fault. The excuses offered for the absence of such evidence, cannot I'm afraid be accepted. We ourselves have found one well-displayed fault at the foot of a waterfall (the Dehenella Falls) where they should be expected to occur, if current theories are accepted. It is even possible that pairs of waterfalls in adjoining streams, so often found in the Central Highlands are indications of a fault line. While we do not deny the possibility or even probability of multiple block faulting we quote as a warning the saying that "one swallow does not make a summer" and add "nor does one fault make a fault complex."

On the contrary, there is evidence that some of the inward dips along the south-facing scarps of the Central Highlands are due, not to tilting, but to overfolding towards the south (as for example on the Balangoda-Kaltota road, the Belihul Oya-Horton Plains path, and the Non Pareil Estate road), and it is certainly more than a coincidence that so many scarps are to be found in charnockite rocks which, as is well known, are more resistant to erosion than normal Khondalites.

May we make the plea therefore that while certain indications might induce us to flights of fancy into the realms of hypothetical crustal movements (necessary as such flights are to daily living), we should refrain from dogmatic assertion until we can provide demonstrable and conclusive proof that such movements have actually taken place. Even then, it is better as one's professor used to say, "to keep your foot in the door when closing it." The method of "multiple working hypotheses" is surely the best for the scientist—especially so for the geologist and geomorphologist.

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## CLIMATE, WEATHER AND CROPS

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University of Reading*

## INTRODUCTION

Climate and weather both have a profound influence on crops, but their influences are of very different kinds. Generally speaking it is weather that causes the great disasters and tragic losses, but it is climate that determines the yield and the success of the crops that escape the disasters of weather. Many crops have a critical upper and lower limit to the temperature and rainfall that they can endure, severe frost or scorching heat may kill them completely in one night or in one day, the disaster is immediate and the failure complete. Prolonged drought or flooding cause a slower, more lingering death, but the disaster is quite as complete. It is important to know how often the unbearable extremes are likely to occur in the climate of a place and the wise farmer studies the statistics of extreme values before he decides to plant vulnerable crops.

Provided that the disasters of extreme weather conditions are avoided, the yield and the quality of the crop depend on the climate of the growing season. The regularity and reliability of the yield will depend on the regularity with which the weather remains faithful to the climatic mean—variable weather means, generally, variable crops.

## WEATHER AND CROP

There will only be time to discuss one example of the influence of weather and one of the effects of climate. For the influence of the weather I have chosen the apple crop in Britain. The greatest disaster that can happen to an apple-grower is a killing frost in late April or May. The apple tree is hardy and can stand any amount of frost in the winter when it is resting. In fact it must have cold weather then; the buds will not open or the fruit will not develop in the following summer unless the tree has experienced temperatures below 45°F. (7°C.) for 1,000 hours during the winter. This requirement makes it impossible to grow apples in tropical climates which have no winter.

But when the leaf and flower buds begin to develop it is very sensitive, its vulnerability increasing as follows:—

Stage of Development of Fruit Buds.				Temperature Causing Injury
Buds tightly packed	...	...	...	10 — 20 F
Buds opening and showing colour	...	...	...	24 — 26
Buds fully open	...	...	...	27 — 28
Fruit formed	...	...	...	27 — 28

An early spring will bring the apple tree to this stage in mid April, a late one by the end of the month; that is the dangerous time. The mean minimum temperature in mid April is 40°F. (8 degrees above freezing point) but unfortunately there are great departures from the mean. A certain kind of weather, regrettably

common, brings frosts nearly every year, and often the frost is a killing one. The first sign of impending disaster is a deep, slow-moving depression, behind which occurs a strong northerly wind which imports great quantities of cold air, not much above freezing point, from Scandinavia or Russia. Behind the depression is an anti-cyclone with calm weather and cloudless skies. Strong nocturnal radiation under these conditions causes the temperature to fall below freezing point and the damage is done.

The disastrous May frost of 1944 will serve as an example. The observations at Reading were as follows:—

Table 1.

May	Bar. 9 a.m.	Temp. 9 a.m.	Dew Pt. 9 a.m.	Wind 9 a.m.	Force 9 a.m.	Cloud 9 a.m.	Max. Aftn.	GRASS Min. Min. Sunrise	
6	29.9	50	37	N.	2	8	56	41	37
7	30.3	49	33	N.E.	2	1	58	30	24
8	30.3	51	41	S.W.	1	0	64	32	26
9	30.4	52	37	S.W.	1	3	66	34	29
10	30.2	60	40	S.W.	1	5	69	41	35

It can be seen that wind velocity and relative humidity are the significant factors and can be used as a means of estimating the nocturnal fall of temperature and hence the likelihood of killing frost. At Cranwell, in Lincolnshire, the following formulae are said to apply:—

Mean Wind Speed expected during the night				Relative Humidity at 3 p.m.	Formula for obtaining Night Minimum (D=Dew Point at 3 p.m.)
Less than 7 m.p.h.	...	...	...	Less than 85%	D — 8
				More than "	D — 6
7—14 m.p.h.	...	...	...	Less than "	D — 4
				More than "	D — 1
More than 14 m.p.h.	...	...	...	Less than "	D — 2
				More than "	D — 0

This formula applies at Cranwell (Lines).

Figures for last column can be found by experiment to apply to any site.

The cold air flows down the valley sides, and the worst damage happens in enclosed hollows. Fruit-growers have learnt, by experience, not to plant orchards in such places, but there are still many old orchards in valley bottoms and they often lose their fruit unless fires are lit to keep the air warm and moving.

Such frosts occur nearly every spring. Between 1927 and 1944 only two Mays in 17 years were free of frost. Not all frosts are severe enough to bring real disaster, but severe ones are frequent enough to make the British apple crop very variable from year to year. In 1934 the commercial apple crop in the United Kingdom was 395,000 tons, but in 1935 there was a severe frost on the night of May 16th–17th and the crop that year was less than 100,000 tons. Helped, probably, by this enforced rest the next year's crop (1936) was a bumper one of

385,000 tons. In 1938 frost on the night of May 9th–10th reduced the crop to 100,000 tons, but 1939 was frost-free and the crop was a record one of 450,000 tons. It is a characteristic of the British climate—as of most transitional climates in maritime situations—that when spring comes it does not stay, but winter returns; then spring comes back again, followed perhaps by a few more days of winter. In continental climates, such as Canada, once winter has gone it does not return. Their climate is more reliable than ours—and so is their apple crop, as these figures show.

Maximum variation of apple crop (1932–36):

Britain	...	...	298%
Canada	...	...	37·5%
U. S. A.	...	...	30%
Australia	...	...	17%

The effect of frost on the apple crop is a direct one, but I might give as one instance of an example of indirect effects of weather on crops—the incidence of potato blight. This is an all-too-frequent pest, especially in mild damp weather. It was mainly this pest that caused the great disaster in Ireland (the potato famine) in the middle of the last century. In 1841 the population of Ireland was more than 8 millions and the potato was the staple food of nearly all of them. It gave a very large yield and was easy to cultivate. Within 10 years the population had been reduced by starvation or emigration to half of what it had been. Mild damp weather favours the blight, but it is possible to anticipate an outbreak because the necessary conditions are established with some precision. It appears when (i) minimum temperatures (at night) do not fall below 50° and (ii) the relative humidity remains above 75% for two days. Once started its further progress depends on (i) absence of hot dry weather which kills the *conidia* on the leaves and (ii) heavy dew or rain which washes the spores into the soil and carries the infection to the tubers, thus affecting the crop.

These two examples show that in general weather is the enemy of the farmer—one could multiply examples indefinitely. But climate is the farmer's friend if he studies it intelligently and co-operates with climate instead of fighting against it.

#### CLIMATE AND CROP

The biggest yields and the most reliable harvests are obtained by growing each crop in the region whose climate most closely approximates to the optimum conditions for the crop. Thus mass production for canning or for export occupies the central belt where the crop grows most readily and most easily, *e.g.* corn in the middle west of the U.S.A., potatoes in the fenland around the Wash in Britain.

But to get better prices, it often pays to grow crops at the wrong season or in the wrong places near the limits of the crop's range, *e.g.* early vegetables. These attempts at unnatural cultivation involve taking risks, and early potatoes sometimes fall victims to frost. The risk is worth taking for the best prices, but it is prudent to minimise the risk. So "earlies" are generally grown in coastal situations (*e.g.* Florida) or on islands (*e.g.* Channel Islands) where the temperature range is small and frost is rare, or on south-facing slopes for the sun's warmth and for better air drainage.

In general the optimum climate for each crop has been discovered long ago by trial and error; sometimes the knowledge has been bought at a high price. But much research is going on to establish more precisely the relation between climate and growth. The most important investigations concern the requirements of the crop for water and warmth.

As an illustration I will deal with the estimation of the heat requirements of plants; naturally they differ for each plant. Some are suited to the amount available in tropical climates (*e.g.* bananas or cotton) some to sub-tropical (*e.g.* oranges or maize) some to temperate (*e.g.* apples or wheat) while those crops making the smallest demands are the only hope for high latitude (*e.g.* cranberries or rye).

Generally speaking growth does not begin until the temperature passes some threshold value which can be determined experimentally. For temperate crops like wheat this is about 42°F., for maize 50°, for cotton 62°. The next problem is to establish a correlation between rate of growth and temperature. Lehenbauer measured the rate of growth of seedlings of maize and, from his figures, it is clear that too much heat is as bad as too little and that beyond 30°C. the rate of growth falls off rapidly and comes to a standstill at about 55°C. In practice, however, the temperature even at mid-day in the maize belt U.S.A. seldom exceeds the optimum and broadly speaking, the warmer the weather the faster it grows.

It would not be wise to accept these results as a full answer to the question because they apply only to the growth in length of the vegetative parts of the seedlings of one variety of maize growing in one place in U.S.A. with the available soil moisture kept artificially up to field capacity.

It is now well known that each crop has different heat requirements at each stage in its development—germination, growth of leaves and stems, flowering, fruiting and ripening. At each of these stages there is a threshold temperature, an optimum and a maximum beyond which more heat checks development and finally kills.

The easiest and most reliable procedure is probably to measure the total heat requirements of each variety of each plant from the date of planting to the attainment of the ripe condition for harvesting. Much work on these lines has been done by Professor Thornthwaite at the Johns Hopkins Climatological Research Station at Seabrook, New Jersey. In the process he has been able to effect valuable economies in the working of Seabrook Farms Inc., a group of four farms of about 1,000 acres each, in the centre of which is a huge processing plant for canning and deep freeze. The labour force employed is very large, both on the farms and in the factory and it often happened that the factory stood idle because there were no crops ripe and ready to process. At other times they had to work day and night in the fields (by floodlighting) to get the crops in before they passed their peak of condition.

Having determined just how long each crop needed, Professor Thornthwaite was able to schedule the planting dates in such a way that the crops came forward, as in a queue, at the precise rate at which the factory could cope with them. The first step was to plant a number of experimental plots with different varieties of

crops and to see how long they took to grow. In this way he determined experimentally that in the particular year in which the experiments were made Alaska Peas planted on 1st March were ready for harvest 96 days later, but planted on 15th June they came to harvest in 34 days. Other dates are :

Planting Date		Harvest Date		Days to Maturity
March 1st	...	June 5th	...	96
March 31st	...	June 10th	...	71
April 30th	...	June 20th	...	51
May 31st	...	July 7th	...	37
June 15th	...	July 19th	...	34

This demonstrates that the necessary heat units are acquired faster, of course, in summer than in the cooler spring weather. Similar experimental planting of other crops showed, for example, that in order to be ready on 15th September :

Golden Cross bantam sweet corn should be sown on	June 26th
Fordhook Lima beans	July 1st
Detroit dark red beets	July 17th
Victory freezer peas	July 29th
Thomas Laxton peas	Aug. 2nd
Old Dominion spinach	Aug. 8th

Of course there are variations from year to year ; in a warm spell the heat units accumulate faster and all crops are accelerated ; in a cold spell all crops growing at the time are held back. But they are accelerated and retarded together and keep their approximate places in the queue, up to this point the method is largely empirical. Though the economic advantages of such a scheduling of crops are enormous and the economy of labour effected is very great it is not scientifically satisfying ; the obvious next step is to determine the value of a heat unit and then to determine the number of heat units demanded by each crop. The former could be done by equating the time periods with the temperature records of the season during which the crop was growing. But this cannot be done until we can discover the true way of measuring the nature of the heat that affects growth. It is unlikely that this will be a simple function of air temperature, or of soil temperature. In fact Thorntwaite is satisfied that the best measure of heat is given by the evaporating power of air. According to him the laboriously calculated unit known as " evapotranspiration " can be used as a heat-unit—being the amount of heat required to use up a certain equivalent of rain by the combined processes of evaporation from the surface and transpiration by the plant cover of the soil.

This method is very circuitous and it is worth trying some simpler basis of assessment. First comparisons suggest that this might be " Accumulated Temperature " measured in day degrees above some threshold value to be determined by experiment. One day degree is a temperature of 1 degree above the threshold maintained for one day. Thus the threshold temperature for wheat is said to be 42°F. If the mean temperature of one day is 50°F., that day has accumulated 8 (50-42) day degrees. The total of such day-degrees added up for each day during growth is the " Accumulated Temperature ".

As an example we may take the citrus fruits whose threshold temperature is said to be 50°F. In the table month degrees are used as the units; they may be converted to day-degrees by multiplying each month's total by the number of days in the month.

Table 2

## CITRUS FRUITS

Minimum for growth of trees 50°  
 Maximum „ „ „ „ 95°  
 Optimum „ „ „ „ 86°

		J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Month Degrees > 50 °F.
Oporto	a.	44	44	49	50	61	65	69	66	63	60	57	52	83
	b.					11	15	19	16	13	10	7	2	
Seville	a.	52	56	60	64	70	78	85	85	78	68	60	53	209
	b.	2	6	10	14	20	28	35	35	28	18	10	3	
San Jose	a.	48	51	54	56	59	64	67	66	64	60	54	48	95
	b.		1	4	6	9	14	17	16	14	10	4		
Fresno	a.	46	52	55	61	67	75	82	80	73	65	55	46	165
	b.		2	5	11	17	25	32	30	23	15	5		
San Luis	a.	52	54	55	56	58	62	64	65	65	62	58	53	104
	b.	2	4	5	6	8	12	14	15	15	12	8	3	
Riverside	a.	52	54	56	60	64	70	76	76	70	65	58	53	154
	b.	2	4	6	10	14	20	26	26	20	15	8	3	

a=Mean monthly temperature.

b=Accumulated temperature above 50°F.

At Oporto the orange trees bear fruit, but it does not ripen; it remains about the size of a golf-ball and is as inedible as one. Nor does it ripen at San Jose or San Luis—all have less than 105 month degrees, but the 154 month degrees at Riverside, Cal. cause the fruit to ripen. Somewhere between 105 and 154 month degrees seem to be the minimum needs of warmth for ripening oranges.

The threshold temperature for the date-palm is 18°C. Algiers has only 652 day-degrees between May and October and the dates do not ripen on the palms; Orleansville has 788 day-degrees and only early-ripening varieties are successful, but at Biskra (1836) most varieties ripen successfully. Some varieties, such as Degli Nour, need 2,000 day-degrees.

## CONCLUSION

This very brief study of the temperature needs of crops and fruit shows that the control of growth and ripening by temperature is a very complex matter in which much work remains to be done. And I have not mentioned water need, or the needs for sunlight, atmospheric humidity, etc. There can be no doubt that water need is equally as important as the need for warmth.

Even in England, with its generally humid climate it is being more and more realized that supplementary irrigation in spells of dry weather would greatly increase both the yield and the quality of the crops. More and more farmers and market gardeners are installing overhead irrigation systems (artificial rain). The quantity to be added in order to keep the soil moisture up to field capacity is becoming better known owing to the work of Dr. Penman at Rothamstead Experimental Station and of Dr. Thornthwaite at Seabrook Farms.

At last it is beginning to be realized that the climatologist has a contribution to make to scientific agriculture. Now that the rapid growth of population in nearly every country in the world demands an ever increasing food production, with undernourishment or starvation as the grim alternatives, his services are more and more urgently demanded.

## IRRIGATION IN NEW SOUTH WALES

By C. C. CORBETT

The problems connected with irrigation in Australia are very different to those with which the people of Ceylon have to contend as the Australian rainfall is very much less in actual annual measurement; moreover, it is spread over the whole of the year in unpredictable individual precipitations and much of the total falls at such times of the year as to be of little use to cultivators.

By this I mean that very often a heavy storm will occur in mid-summer and although this is useful for filling storage for domestic and stock water-supply, it is not of great use for crops as the heat rapidly evaporates the moisture which has fallen leaving the ground baked hard. Whereas in Ceylon the monsoons are, within a fairly narrow margin, predictable as to the date of breaking, and maximum advantage can be taken of the natural rainfall.

In Australia it is necessary to construct large storage reservoirs in order to insure irrigated cultivation against loss due to drought. The practise of irrigation is comparatively recent in Australia as English settlement only commenced approximately 166 years ago and the signs are that previous populations had been unable to establish themselves in permanent towns or cities because of the uncertainty of water supply, and had been nomadic in their habits, following the available supplies of water from river to river.

Irrigation is at present more intensively developed in the south-eastern portion of the continent, particularly in the states of New South Wales, Victoria and South Australia. I propose to speak mainly of New South Wales as that is the State from which I come and of which I have the more complete knowledge.

New South Wales can be roughly divided into three zones :

The coastal zone which extends from the east coast of New South Wales to the Dividing Range and which is a comparatively narrow strip of country. Generally speaking, the rainfall in this strip is not unsatisfactory for production of crops without irrigation, and it is within this zone that the dairying industry is largely established. There is one large conserving storage dam under construction at present in this zone on the Hunter River at Glenbawn, as this river valley suffers from occasional droughts, which although of only short duration, are of sufficient severity to hamper seriously the dairying industry.

Along the central zone of the Dividing Range, which is fairly narrow, is situated almost the whole of the elevated land within the State and this forms the watershed from which the rivers of the coastal and the western zone originate. The maximum height of this range does not greatly exceed 7,000 feet at the highest point, Mount Kosciusko, and consequently, with the exception of a comparatively limited area adjacent to that mountain, receives no snowfall at any time. This means that the majority of the rivers rising in the Dividing Range have to depend on rainfall for their discharge of water. It will therefore be appreciated that without large conserving dams it is impossible to consider any stabilised irrigation schemes within New South Wales.

The western zone comprises almost entirely flat, plain, alluvial country and geologists say that a large area of this zone was at one time an estuary of the sea which was gradually reclaimed by siltation at the end of the glacial age. It is in the plains of this zone that practically the whole irrigation areas of New South Wales are situated.

At present there are three large conserving dams which are used for irrigation. On the Murray River, which forms the boundary between New South Wales and Victoria, and whose downstream section flows through the State of South Australia to the sea, has been constructed the Hume Dam. This dam has a storage capacity of 1,250,000 acre feet and construction is now proceeding to increase the storage to 2,500,000 acre feet. The water from this dam is controlled by a special Commission which includes a representative from each of the Commonwealth, New South Wales, Victorian and South Australian Governments, and the inter-state agreement under which this Commission operates, requires that a certain minimum quantity of water shall be made available in each year to South Australia, the remaining water amounting to approximately 2,000,000 acre feet per year, being shared equally by the States of New South Wales and Victoria.

It will be noted that the "regulated flow" is considerably more than the actual capacity of the storage and this is because during the spring, that is about October-November, the spill-way of the dam is discharging and there are also a number of tributaries which enter the river below the dam, the water from which can be used for irrigation. This river rises in the mountain ranges near Mount Kosciusko and consequently has some snow-fed catchment and is undoubtedly the best river in Australia from the point of view of irrigation.

The Murrumbidgee River is the next most important river in New South Wales as a portion of its catchment is adjacent to the snow-fed head waters of the Murray River and to that extent has a fairly reliable inflow. On this river, the Burrinjuck Dam conserves 650,000 acre feet of water and construction is almost completed to increase this to 850,000 acre feet.

On this dam depend the Murrumbidgee irrigation areas which are the earliest and still the most intensive of all the State's irrigation schemes.

The Lachlan River is the only other river on which there exists at present a large storage dam. This dam is the Wyangala Dam and contains, when filled, approximately 350,000 acre feet of water. The water from this dam is used to maintain a flow throughout the summer in the Lachlan River, which would otherwise cease to flow for long periods.

Storage dams are under construction at Burrendong on the Macquarie River and at Keepit on the Namoi River. These dams will not be completed for some time and their purpose is to maintain flow in the rivers on which they are constructed, and to provide water for diversion for irrigation.

The longest river in New South Wales is the Darling River which rises in Queensland and flows in a very tortuous course to join the Murray River. The flow in this river is intermittent and varies from serious floods to periods when the

river is completely dry, except for water holes in its bed, for months at a time. The New South Wales Irrigation Commission is constructing a storage on this river which will be of somewhat different type to the large dams on the other rivers. In this case it is proposed to use a number of large shallow lakes, and by the construction of inlet channels and bunds, where necessary, to divert flood water from the Darling River into the lakes and store it there for release into the river during periods of low flow. The capacity of this system of storage in natural lakes, when complete, will be 3,500,000 acre feet.

In the northern portion of the State, water can be obtained by deep boring into the artesian basin. Some bores are over one mile deep and many thousands of acres which otherwise would be completely dry and incapable of carrying any stock are supplied with water. The water from the artesian bores is mineralised and for that reason is not suitable for irrigation. It is also generally considered to be unsuitable for human consumption, although in some cases it has been possible to locate a bore from which fresh water fit for domestic use can be obtained.

The foregoing summarises the action necessary to provide water for irrigation in New South Wales, and the State has many years development work ahead in its construction of storage dams and channel systems to carry the water to the lands to be irrigated. The time required for completion of all practicable schemes will depend on the availability of money to finance construction work, but it may be said that at least a half century must elapse before it can be considered that final development may be reached.

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Notes of lecture delivered to the Ceylon Geographical Society at the Physics Lecture Theatre, Colombo University, on 18th November, 1954, by Mr. C. C. Corbett, Member of the U.K./Australian Rice Mission.



TABLE OF CEYLON SOILS

Soil Groups and Series	Location	Rainfall Inches	Geology	Vegetation
<b>1. Red to Yellow Laterite, Lateritic and Non-lateritic Soils—</b>				
(i) Ultra wet zone yellowish lateritic loam ... ..	Massena, Balangoda	Over 200	Charnockite	High jungle
(ii) Ultra wet zone yellowish red lateritic loam ... ..	Ambepussa	117	Charnockite	Coconuts and garden crops
(iii) Wet zone yellowish red lateritic loam ... ..	Peradeniya	94	Khondalite	Mana grass and tea
(iv) Dry zone reddish brown non-lateritic loam ... ..	Anuradhapura	55	Gneiss	Dry zone crops and fruits
(v) Dry zone red lateritic loam ... ..	Sigiriya	76	Bintenne gneiss	Low jungle
(vi) Semi-dry zone dark grey non-lateritic loam ... ..	Minneriya	79	Recent over felspathic gneiss	Medium jungle
(vii) Semi-dry zone grey brown sandy loam ... ..	Unichchai	80	Acid gneiss	Scrub and low jungle
<b>2. Limestone Series—</b>				
(i) Brick red loam ... ..	Timevely, Jaffna	50	Miocene limestone	Tobacco and garden crops
(ii) Grey loam ... ..	Delft Island	46	Miocene limestone	Pasture grass and dry grains
(iii) Black loam ... ..	Tunukkai	40	Limestone over felspathic gneiss	Scrub jungle
(iv) Chocolate red loam ... ..	Nalanda	85	Dolomitic limestone	Tobacco, citrus, etc.
(v) Brownish red loam ... ..	Tabbowa	46	Jurassic limestone	Coconuts
<b>3. Humic Series—</b>				
(i) Wet grassland (patana) ... ..	Kandapola	98	Khondalite	Grass and rhododendrons
(ii) Dry grassland (patana) ... ..	Welimada	54	Khondalite	Grass, fruits and tea
(iii) Fernland (kekilla) ... ..	Liniyawa	164	Charnockite	Ferns, etc.
(iv) Peaty loam ... ..	Labuduwa	102	Recent cumulose	Paddy
<b>4. Pleistocene Plateau Deposit Series—</b>				
(i) Brownish red sand ... ..	Marawila	65	Pleistocene deposits, residual	Coconuts
(ii) White sand ... ..	Negombo	90	do.	Cinnamon and coconuts
(iii) Reddish brown loam ... ..	Middeniya	67	do.	Fruits, citrus and rotation crops
<b>5. Recent Series—</b>				
(i) Brown sandy loam ... ..	Manampitiya	70	Alluvial	High jungle and tobacco
(ii) Yellowish brown loam ... ..	Peradeniya	94	do.	Paddy
(iii) Dark grey clay loam ... ..	Tambalagam	75	Alluvial over biotite gneiss	Paddy

## THE SOILS OF CEYLON\*

By A. W. R. JOACHIM

(Summary of Presidential Address to Section B, Ceylon Association  
of Science, May, 1945)

THE SOILS OF CEYLON AND THE FACTORS  
GOVERNING THEIR CHARACTER

The chief factors influencing the development and character of local soils are climate, nature of parent rock, vegetation and topography.

**Climate** is undoubtedly the predominant characterizing factor in the case of the majority of our soils. The high temperatures and heavy precipitations alternating with periods of dry weather, which are experienced over a large part of the Island, are eminently favourable for chemical weathering and the development of laterite (*cabook*) or lateritic soils where the nature of the parent rock-material permits. It is not often, however, that pure laterite soils are found in Ceylon, the great majority of the coloured soils being of the lateritic type. This is all to the good, as laterite soils are generally infertile while those of the lateritic type are of fair agricultural value. Under other conditions, for example when the rainfall is deficient or the drainage impeded, as in paddy soils, or the geological material unsuitable for laterisation as in the case of the Jaffna limestone, the tendency is for the weathering to be of the kaolinitic or ordinary type.

**Climate** also determines, to a large degree, the organic status of our soils. Over the greater part of the Island conditions are more favourable for the decomposition of organic matter than its accumulation. Our unirrigated cultivated soils are generally poor in organic matter, frequently containing less than 2 per cent. of this constituent, the exceptions being the soils of virgin forests, grassland areas and fernlands. In the soils of the two latter, the organic matter content occasionally rises to 10 per cent. Under anarobic conditions, as in wet paddy soils, the organic matter contents are higher than in adjacent high land.

**Geology** as a soil-characterizing agent is best exemplified in the case of the Jaffna soils associated with limestone parent material. The uniform, free-draining, deep red soils, similar to the terra rossa of Mediterranean regions, to which these limestone rocks give rise, are independent of climatic influences. The nature of the geological material has also, to a large degree, determined the character of certain soil types in the low-country where Pleistocene plateau deposits, first described by Wayland (9), have been reported to come. These are the red and brown sandy soils of the Western and North-Western Provinces and the white cinnamon soils. There is also evidence all over the dry zone, and particularly where the dome-like ridges ("turtle backs" in Wayland's phraseology) of red and brown loams occur that the upper horizon of these soils is identifiable with the red earth stratum of the Pleistocene deposits.

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\* Reprinted from Bulletin of the Ceylon Geographical Society, Vol. II, 1947, pp. 12-18.

From the standpoint of the soil scientist the crystalline rocks of Ceylon, whether gneissic or igneous, are of significance only in so far as they are geologically basic or acidic. The acidic members of either group, like the granites or granulites, generally give rise to light coloured and textured soils, poor in lime, but likely to be rich in potash. Soils derived from basic rocks like the norites, are darker red in colour and generally heavier in texture, while in regard to plant food constituents they tend to be rich in lime and poor in potash. The actual composition of the soil will, however, depend on the kind of weathering to which the rock from which it has been derived was subjected, and the subsequent pedogenic (soil-forming) processes it has undergone.

The influence of **vegetation** on soil type in Ceylon is clearly seen in the *patanas* (grasslands) of the Central and Uva Provinces and the *kekillas* (fernlands) of Sabaragamuwa. In the case of the wet *patanas* and fernlands, the strongly acid soil conditions induced by the vegetation and almost continuous rainfall contribute to the elimination of all but a few tree species. In the dry *patana* area intense precipitation during the rainy season causing severe soil erosion, a prolonged dry season when soil moisture is reduced to limits below the minimum required for the growth of shrubs and trees, and strong desiccating winds are additional factors responsible for the permanence of this vegetation type. Soil data show that while the surface horizons reflect the effect of the vegetation on soil composition and texture, the C horizons (sub-soils) of both grass or fernland and adjacent forest land are very similar physically as well as chemically. The drainage of the *patana* sub-soil tends, however, to be somewhat defective.

The soils of the highlands and of the paddy areas furnish the best examples of the effect of **topography** on the character of local soils. In the former, severe erosion caused by the heavy and intense rainfall has depleted the soils, for the most part, of the valuable surface soil with its accumulation of humus, colloidal material and easily-available plant fertilizing constituents. In the low-lying paddy areas, this wash from the hills is deposited. In these paddy soils the influence of water movement as governed by topography is seen to advantage. Typical paddy soils are generally, for the greater period of the year, either submerged under water or poorly drained, the water table being at or near the surface. As a result the soils are of the characteristic grey type, the lower layers being bluish grey to dark grey in colour and mottled brown by hydrated iron oxides. Under well-drained conditions, these soils make quite good arable loams. Where the soils are water-logged, however, peat-like deposits such as those at Muthurajawela in the Negombo District and in the gemming areas of the Island, accumulate occasionally to depths of 10 feet or more. Other examples of soils in which topography determines their nature are the alluvial loams and silts.

#### CLASSIFICATION OF CEYLON SOILS

Based on the edaphic factors, the soils of Ceylon may be classified into the following major groups and series. The rough distribution of these soil types is shown in the Provisional Soil Map furnished (Fig. 1).

## 1. Zonal soils in which climate is the dominant soil-characterizing factor.

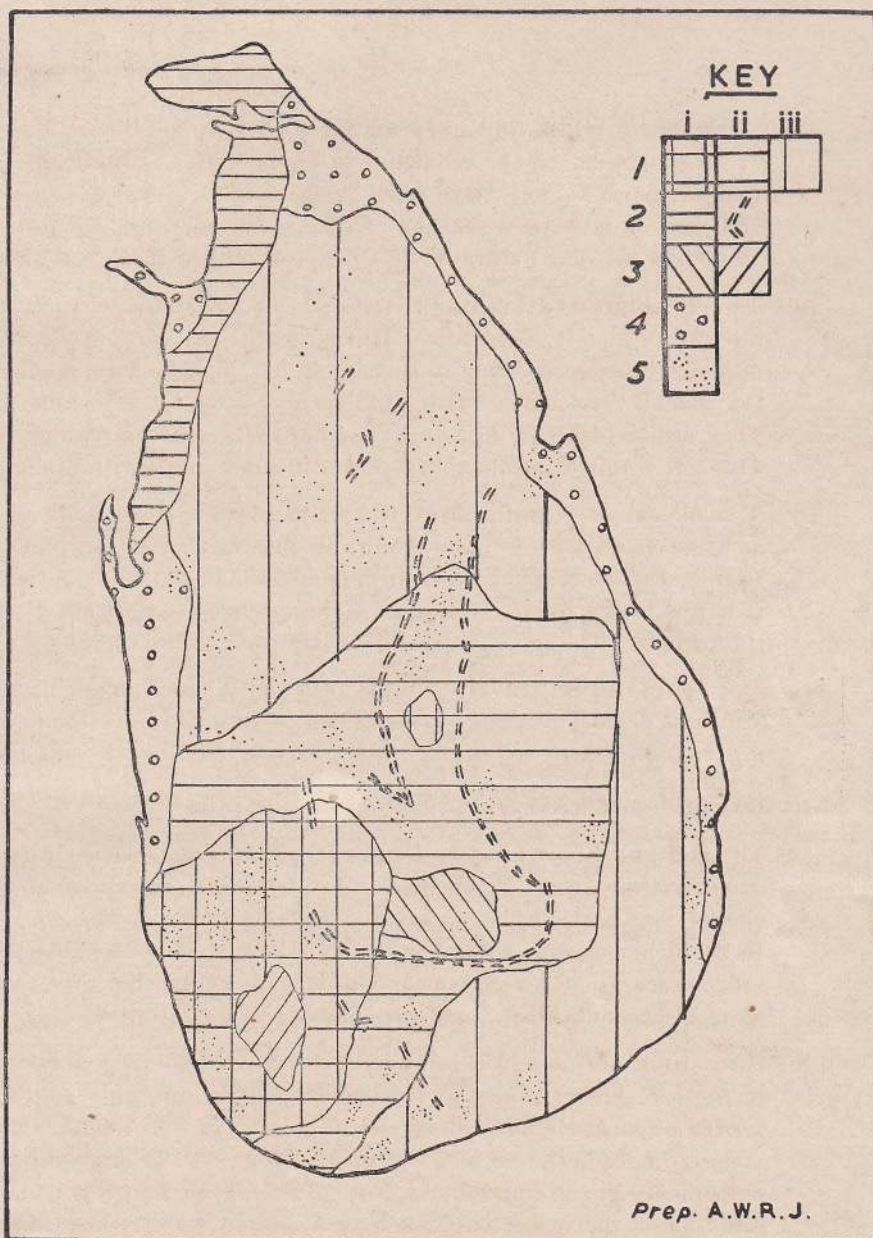
- (i) The laterite and lateritic soils—in Ceylon true laterite, the material used for bricks and known locally as *cabook*, occurs mainly in the wet low-country zone. The material, which shows a characteristic reticulated structure, is of variable depth and is usually overlain by gravelly loam. The **reddish yellow loams** which, morphologically should be classed as laterite soils are again mainly lateritic in nature. The **yellow soils** formed under almost-continuously moist conditions and overlain by humic loams, and those developed under extremely heavy rainfall conditions (over 125 in. per annum) do, however, come within the category of laterite soils. The **reddish loams** are mainly of the lateritic type. With the exception of typical laterites, these soils are fairly deep loams of varying texture, containing ironstone nodules and small boulders in varied proportions. They are generally well-drained, especially the reddish loams, hard but friable when dry. The vegetation is generally forest and high jungle except in the wet *patana* (grassland) zone. They are cultivated with permanent crops—tea, rubber and coconuts generally.
- (ii) (a) The dry zone (40"—75" annual rainfall) red and reddish brown lateritic and non-lateritic soils. These are well-drained, friable loams of fair depth. The **reddish brown loams** are frequently non-lateritic in nature. They overlie gravelly loams grading down to decomposing rock. Their natural vegetation is high and medium jungle. They are best suited for arable crops and, where irrigation is feasible, for paddy. Fruit crops are also grown on them where the rainfall conditions are satisfactory.
- (ii) (b) The **dark grey loams** occur in low-lying locations. They are of variable depth and almost invariably non-lateritic in nature. Their drainage is imperfect. Low jungle is their natural vegetation, but occasionally what are known locally as *damanas* or parklands occur on them. They are typical paddy soils.

In certain localities in the dry zone, **shallow grey brown light sandy loams** derived from acid felspathic gneiss occur. These overlie decomposing rock and are non-lateritic in nature. Their natural vegetation is low jungle and scrub.

## 2. Intrazonal soils associated with limestone.

- (i) The **brick red loams** of the North and North-Western part of the Island derived from Miocene limestone. Uniform in texture, colour, etc., down to parent rock, which occurs at a depth of from 1 to 30 feet from the surface. These soils are very well drained, and non-lateritic in nature. Annual crops thrive well on them when manured with bulky organics. These appear to be typical "terra rossa" soils. The natural vegetation is scrub and palmyrah palm.

- (ii) The **greyish white and grey loams** derived from Miocene limestone. They are similar to the rendzinas or chalk soils of Britain and are of shallow depth. They have fairly high reserves of calcium carbonate and are non-lateritic in nature. They are mainly suited for paddy and arable crops. The natural vegetation is scrub and palmyrah palm.
  - (iii) The **chocolate red loams** derived from or associated with crystalline limestone, mainly dolomitic. Heavy loams of varying depth, but imperfectly drained owing to their relatively high magnesium contents. Occasionally associated with a high proportion of ironstone gravel. They are non-lateritic in type. The natural vegetation is high jungle. This soil is suited for annual crops and for tree crops with drainage.
  - (iv) A small extent of **soils similar to the black cotton soils** of India and associated with Miocene occurs in the North-Western part of the Island near Tunnukkai, with an annual rainfall of about 40 in. The soils are heavy loams. Nodules of limestone occur within a foot of the surface. The natural vegetation is zerophytic low scrub.
  - (v) **Red loams over gravelly loams** occur in a small extent of land at Tabbowa near Puttalam. Concretions of limestone are found in the lower strata. This soil type is similar to the red Miocene soil.
3. **Soils derived from Pleistocene and sub-Recent deposits.**
- (i) The **red and brown sandy loams** (typical coconut soils). Generally deep, well-drained light loams and sands with no apparent profile change, except that the surface soil is slightly darker in colour owing to its higher organic matter content. These soils occasionally overlie gravelly loams. Though poor in all plant nutrients, they give excellent crops of coconuts when manured. They are non-lateritic in type.
  - (ii) **Cinnamon soil** is a bleached white sand derived from (i) and occurring in areas of higher rainfall. Extremely poor in nutrients and characterized by a clay-humic illuvial pan at a depth of 5 feet or so. Drainage is accordingly defective, and for successful growth of crops other than cinnamon, *e.g.* coconuts, drains have to be cut through this pan. This soil type is the nearest approach to a ground water podzol, the only difference being the absence of the surface organic layer. The coastal sands are similar to (ii) chemically, but lack the illuvial horizon.
4. **Humic soils** overlying reddish yellow laterite and lateritic loams and clays.
- (i) The typical **grassland (patanas) soils**. These may be divided into two types: (i) the 'wet' patanas which occur in areas of high annual precipitation evenly distributed, and at elevations of 4,000 to 6,000 feet; (ii) the 'dry' patanas with a lower annual precipitation and a marked wet and dry season. They occur at elevations of about 3,000-4,000 feet. The soils of both types are derived from crystalline rocks. The chief feature of the wet patanas soil is a dark brown to black acid humic surface horizon of depth varying from 1 to 3 feet or more, overlying a gravelly layer, superimposed on a mottled reddish-yellow



### PROVISIONAL SOIL MAP OF CEYLON.

#### Explanation of Key

1. SOILS DERIVED FROM IGNEOUS & GNEISSIC ROCKS
  - (i) Laterite (cabook) and lateritic reddish yellow loams and gravelly loams of ultra wet zone.
  - (ii) Reddish to yellowish red lateritic loams of wet zone.
  - (iii) Lateritic & non-lateritic red, reddish brown and dark grey loams of dry zone.
2. SOILS ASSOCIATED WITH LIMESTONE
  - (i) Red Loams derived from Miocene limestone.
  - (ii) Brownish red loams Associated with crystalline limestone.
3. HUMIC SOILS OVERLYING YELLOWISH TO REDDISH LATERITE AND LATERITIC LOAMS AND WHITE SANDS.
  - (i) Grassland (patana) soils (wet and dry).
  - (ii) Fernland soils (kekilla) soils.
4. SOILS DERIVED FROM PLEISTOCENE & SUB-RECENT DEPOSITS
 

Sandy Soils
5. RECENT ALLUVIAL DEPOSITS, ETC.
 

Paddy (gley) soils.



laterite loam. Drainage is imperfect owing to the compact nature of the sub-soil. Earth slips occur frequently. The wet patanas occur side by side with low jungle of a characteristic type. Tea is their main cultivated crop. This soil may be classified as a **mountain peat**.

- (ii) the dry patanas have only a shallow humic surface horizon which overlies in turn a reddish to purplish loam of variable depth and rock in varying stages of decomposition. The soils are lateritic in type. This type may be designated a tropical **mountain steppe soil**.
- (iii) The **fernland (kekillia) soils**. Acid humic soils occurring in regions of high rainfall and rain forest vegetation. The humic layer does not generally exceed 1 foot in depth. It overlies yellowish laterite and lateritic gravelly loams. The fern is a secondary growth arising from the clearing of the jungle and periodical burning of the succeeding vegetation. These soils are best suited for rubber and tea.
- (iv) The low-lying, ill-drained **peaty soils**. Of variable depth from 1 to 4 feet and over. They overlie loams and clays, not frequently kaolin, and are lateritic in type. These soils are only suitable for paddy cultivation and may be classified as half bog soils. Occasionally, they are inundated with salt water from adjacent lagoons. A variant of this soil type is a low-lying, ill-drained, humic and overlying clay—known locally as *deniya* soil; it is lateritic in nature.

## 5. Azonal Soils.

- (i) and (ii) The reddish brown, grey brown and yellowish brown **alluvial silts, loams and clays** are essentially paddy soils by virtue of their location. They infrequently exhibit a grey horizon being intermittently water-logged. The paddy soils vary markedly in texture from light loams to clays and show equally marked variations in chemical nature.

## SOME OBSERVATIONS ON SHIFTING CULTIVATION IN CEYLON\*

By P. P. UDUGAMA

Shifting cultivation was probably the first form of land utilisation, especially in the Tropics. It is not however confined to the tropical belt, and vestiges of its practice do remain, even to this day, in certain parts of the world, *e.g.* Europe (W. Germany, Finland), U.S.A. (Tennessee Valley before the T.V.A.). The equatorial forest is the home of this crude type of agriculture almost everywhere in the world, but it is more characteristic of regions which have one or more rainy seasons alternating with dry seasons, and hence is characteristic of the Tropical Belts. The system of shifting cultivation, known as *chena* in Ceylon, is called by different names in the other countries in which it is practised—*shamba*, *chitemene* (Africa), *bewar*, *jhum*, *korali*, *dhaya* (India), *taungya* (Burma), *tebasan*, *ladang* (Malay Peninsula), *laingin* (Phillippines), *milpa* (Central America).

In Ceylon, *chenas* are cultivated in land covered with secondary forest (there is very little virgin forest left) or other vegetation. These lands may be private leased, or granted by the Crown. Since private individuals and corporate bodies own only 115 square miles, *i.e.* 0.6% of the 17,000 square miles of forest, the majority of the *chenas* are in Crown land; and since this pernicious system of cultivation is detrimental to the natural growth of forests, the Crown has regulated its cultivation, both in the reserved and 'village' forests. Rules under the Forest Ordinance prohibit clearing for the *chenas*—

- (1) Without a permit from the Government Agent.
- (2) Within 100 yards of a high road or 50 feet of a stream or ridge.
- (3) In any area of forest containing full-grown trees, if there is available sufficient land containing secondary growth of not more than ten years, and
- (4) In any forests reserved for fauna and flora protection, or for the prevention of erosion or the regulation of water-supply.

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\* Reprinted from Bulletin of the Ceylon Geographical Society, Vol. II, 1947, pp. 31-35.

Each cultivator is allowed to clear one or two acres of land after a nominal rent has been paid to obtain the permit. The actual work of burning and clearing the forests begins in May or June, after the rains, when the peasant has finished his work in the paddy fields. The forest is cut down and fired when the leaves and branches are dry, and the firing is helped by the winds at this time of the year. The stumps of the burnt trees are then cut down and a wooden fence is erected around the plot—the chena—to protect the crops from the ravages of the wild boar, elephant, mouse-deer, bandicoot, and the rat. The ash of the burnt vegetation adds phosphates to the soil which is thus changed from slightly acid to slightly alkaline. Ceylon soils are low in fertility and the dictum that ‘shifting cultivation is less a devise of barbarism than a concession to the character of the soil which needs long periods for recovery and regeneration’ is equally applicable to Ceylon as it is to Africa(1).

When this preliminary work is over, the ground is barely scratched with the poor and primitive implements of the impoverished cultivator. A temporary hut in the chena accommodates the whole family which now works as a unit to finish the work of sowing and cultivating before the next rains begin. Various crops are grown together. Cereals which do well in the Dry Zone are preferred as these supplement the supply of rice—*kurakkan* or finer millet (*Eleusine coracana*), *meneri*, panicum millet (*Penicum miliaceum*), *thana hal* or Italian millet (*Setaria italica*).

A rainfall of 15 or 20 inches would suffice during the growing season. *Kurakkan* is usually sown broadcast with mustard (*Brassia junica*). Pulses such as green gram, horse gram, and black gram, besides maize, are also cultivated. Apart from the above pulses and cereals, dry zone vegetables grow with little or no care. However ignorant the chena cultivator may be as regards modern agricultural implements, he is in one respect as good as any Jaffna farmer—no part of his chena will be bare. All types of vegetables occupy every corner of the cleared patch, and creeping plants grow on the wooden fence, on the charred trunks of trees, and on the hut. The usual vegetables include pumpkin (*Cucurbita maxima*), ash pumpkins (*Bemincasa cerifera*), gourds (usually *Curcubita popo*), chillies, brinjal and tomatoes. To protect this garden of mixed cultivation the cultivator must spend many sleepless nights on a platform built on the branches of a tree, scaring away the animals that might do damage to his plot.

This shifting cultivation is confined to the Maha season, viz. July to October. In certain areas in the Anuradhapura and Kurunegala Districts, another crop is grown on the same land after the first has been collected. This is the Yalhena—the chena cultivated during the Yala season from March to July. However, only one crop is grown, which is gingelly (*Sesemum indicum*). The seeds are sown broadcast and the plants grow with little care in the early rains of March and April, and ripen in the dry months of June and July. This same crop is grown in the “tial” lands of the Jaffna Peninsula, and is the most paying cash crop of the chena cultivator.

Fig. 1 shows that the greater area of chena lands is confined to the Dry Zone which receives an annual rainfall of less than 75 inches. In this zone are the extensive areas of Dry Zone Tropical Forest. However, nearly every province of Ceylon has some form of chena cultivation. Though the greatest area of chena land (8,695 acres) exists in the Central Province, in the percentage acreage of cultivated land, the North-Central Province leads all the other provinces in having 8.45% (6,670½ acres) of the cultivated acreage under chena land. The other two important provinces are the North-Western Province (7,849 acres) and the Uva Province (7,770 acres).

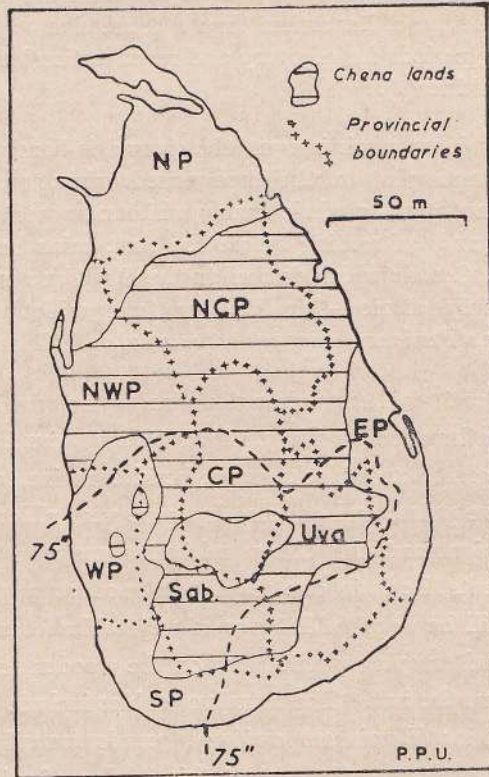


Fig. 1.—Map showing distribution of Chena Lands in Ceylon.

It is significant that the map shows no chena lands in the Northern Province, which, according to the Agricultural Census of 1946, has only 1,240 acres of chena or 0.97% of the total cultivated acreage. In a densely populated, non-forested region as the Jaffna Peninsula, there is no land available for chenas. There are a few acres of "tial" land in Jaffna, corresponding to the chena land of the Wanni, but the practices are quite different. There is however another reason for the absence of chena in the Northern Province, and that is that the Tamils, wherever they may live, never practise chena cultivation. This is evident in the Tamakaduwa District where the Tamils in the villages adjoining those of the Sinhalese, never clear a patch in the forest. This may perhaps be due to the peculiar factors of environment in the land from which the Tamils migrate.

The coastal belt of the Wet Zone also has no land under chena, owing to the fact that there are no forested regions in this thickly populated area. In the south-east is the Ruhuna National Park, adjoining the coastal regions of the Batticaloa District, and in the north-west is the Wilpattu National Park, where no chena is obviously possible. The Central Highlands, especially those over 5,000 feet, form for the most part, Crown Forests.

The chief forms of cultivation and the uses of the abandoned chena lands are similar all over the Island. There are, however, minor but conspicuous regional differences in the subsidiary occupations of the chena cultivator, as well as different forms of the utilisation of abandoned chenas. These differences can be classified as follows :—

(1) The Tank Country : in the “ tank villages, the peasants are primarily paddy cultivators, chenas being only secondary to the paddy fields, and there is plenty of Crown Forest. The practice here is to cultivate the chena patch once in 10 or 12 years, and thus “ rotate ” the land rather than the crops.

(2) Parts of the Badulla District, especially in Wellassa, Bintenna and Wiyaluma : Chena cultivation is the chief occupation, and the villagers exist purely on shifting cultivation. Once a chena area round a village is abandoned, the whole village, consisting of perhaps 10 to 12 families, migrates to another site, where the land can be easily cleared for a fresh belt of chena land. These people are perhaps the poorest in the Dry Zone.

(3) The Wet Zone : the chena, once cultivated, passes into permanent cultivation as in parts of the Kegalle District. The land may be owned either by private individuals or by the Crown. Once the chena crops are put in the land, permanent crops such as arecanuts, rubber, etc. are also planted along with them. These lands eventually become “ peasant holdings ” or are classed as “ high land ” cultivation.

This system of shifting cultivation has been unequivocally condemned by forest experts in every part of the world. Wherever it is found, the system has been discouraged for the following reasons :—

(a) The wasteful exploitation of forests : In Ceylon, one authority reporting on the management and exploitation of the forests has written—“ there are few areas in the world which show the depredations of shifting cultivation worse than in Ceylon ” (2). There is no doubt that shifting cultivation reduces the economic value of the forests.

(b) Soil deterioration and erosion : The firing of patches of forest to clear the land results in the destruction of the vegetation cover of the soil and of the organic matter in it. The removal of the soil cover by rain and wind is thus facilitated.

(c) Formation of “ wastes ” : Only a very poor secondary forest would grow in an abandoned chena patch.

(d) Low returns: In consequence of the niggardly environment and of the primitive implements used, the physical effort of cultivating a chena is out of all proportion to the poor return obtained from it.

Most of the reasons given for the discouragement of this form of land utilisation have viewed the problem from the point of the economic utilisation of the forests; there has been little or no attempt to consider sympathetically the position of the cultivator himself who just manages to eke out an existence in an unhealthy and adverse environment. It is quite true that the Ceylon forests have, within the last two centuries, been destroyed at an increasing rate by chena cultivation; in fact, the question of forest reservation has always been connected with chena cultivation. The government has, to a great extent, succeeded in checking the wanton destruction of forest in the last few decades, and there are now nearly 2,200 square miles of forest in Ceylon. Experts on forestry have recommended the policy of using the chena for reforestation (which the government has not accepted as workable), and discouraging chena cultivation, or alternately adopting better methods of permanent cultivation or rotation of crops. In certain areas teak and jak chenas have been successfully planted, but this fruitful method needs more sustained propaganda, encouragement and inducement by the government.

However much the system is denounced as destructive and uneconomical, forests will continue to be utilised for agricultural purposes until a better system of agriculture is made possible to the chena peasant. The poor cultivator cannot possibly be expected to experiment with and adopt the rotation of crops as done by the Experimental Stations of the Department of Agriculture. One remedy would be to make the peasants the legal owners of chena lands demarcated for certain villages. Then, at least, the pride of ownership might make the cultivator work his plot of land economically and not try to extract the maximum return in the shortest possible time without any provisions for recuperation. In this way, chena lands might in time be converted to areas of 'high land cultivation' so characteristic of Ceylon villages. In order to make such a system work and to persuade the cultivator to settle down to a permanent system of cultivation, his primary occupation as a paddy grower has to be safeguarded by adequate supplies of water for irrigation purposes. In the newly opened "colonies" of the Dry Zone, the peasants are allotted a certain amount of land for paddy cultivation and for high land cultivation, and adequate water is assured to them. The same facilities and encouragement should be offered to these shifting cultivators who have for so many centuries lived in abject poverty in a hostile environment, and to whom the benefits but not the curses of civilisation have for so long been denied.

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## NOTES ON ROCK WEATHERING IN CEYLON\*

With the exception of comparatively limited portions of the earth's crust laid bare by erosion or on steep hill slopes, the underlying rocks are mantled by a soil cover of varying thickness, chemical composition, and state of aggregation. This soil cover varies in character (*a*) under the conditions in which it was formed, and (*b*) with the nature of the parent material. The process by which the rock material is disintegrated and decomposed is termed **WEATHERING**, and is essentially the breaking up of complex unstable compounds with the production of simpler and more stable substances. The rocks, whether of igneous or sedimentary origin, when exposed in any land surface, are subject to a different environment to that in which they were originally formed, and are consequently in a state of instability. For example, an intrusive granite which would have crystallised and consolidated at depth, and which would be in equilibrium under the very high temperature and pressure prevailing at that depth, would be unstable when exposed to ordinary atmospheric temperature and pressure, by removal of the overlying material. In the process of adjustment to its new environmental conditions, physical as well as chemical changes take place, and these are sometimes aided by an additional factor, namely, the vital activity of plant and animal life, most obvious of which is the physical and chemical activity of plant roots. Rock weathering, therefore, is partly a mechanical process and partly a chemical process.

The physical changes which bring about rock disintegration in Ceylon, are, in the main, due to the diurnal changes of temperature of the exposed land surfaces. The chemical changes are conditioned by the amount of rain-water percolation, in addition to the generally prevailing high temperature. Moisture, besides aiding the activity of gases, as in oxidation, plays a more prominent part in chemical weathering such as in hydrolysis, hydration, carbonation and solution of minerals and rocks. We can say in general that the chemical processes are active in the humid (and hot) regions of the Island, and the physical processes (disintegration) predominate in the arid regions.

For purposes of this note we shall consider weathering in the following zones :—

- (1) Weathering in the Wet Zone—more than 75 ins. rainfall per year.
- (2) Weathering in the Dry Zone—less than 75 ins. rainfall per year.
- (3) Weathering in the Limestone Zones.

### Weathering in the Wet Zone

Lateritisation is the most important and characteristic process in the wet zone of Ceylon, acting on different types of rocks under conditions of alternating wet and dry seasons, a ferruginous, vesicular clayey deposit of high porosity resulting. The rocks which are lateritised in this zone include biotite gneisses, hypersthene granites (charnockites), leptynites, and garnetiferous granulites. The chief mineral constituents of these rocks are quartz, felspar, mica, garnet, pyroxene, and varying accessory minerals such as ilmenite, graphite and sillimanite.

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\* Reprinted from Bulletin of the Ceylon Geographical Society, Vol. II, 1947, pp. 19-21.

The process involves principally the dissolving action of slightly acid water on these minerals which are mainly silicates containing aluminium, iron, etc. Silica is liberated in the form of silicic acid, and carried downward by the percolating action of rain-water during the wet season. There is a consequent enrichment of iron and alumina in the upper surfaces of the laterite.

The presence of joint and fracture planes, particularly in rocks of the charnockite group, often assists the process of lateritisation, the joint planes affording easy lines of percolation and subsequently decomposition, so that one often sees residual boulders of unweathered rock in a zone of weathering (Fig. 1). Laterites derived from Khondalite rock types rich in manganese garnets often contain nodules or pellets of hydrated manganese oxide, in addition to the ferruginous nodules usually found.

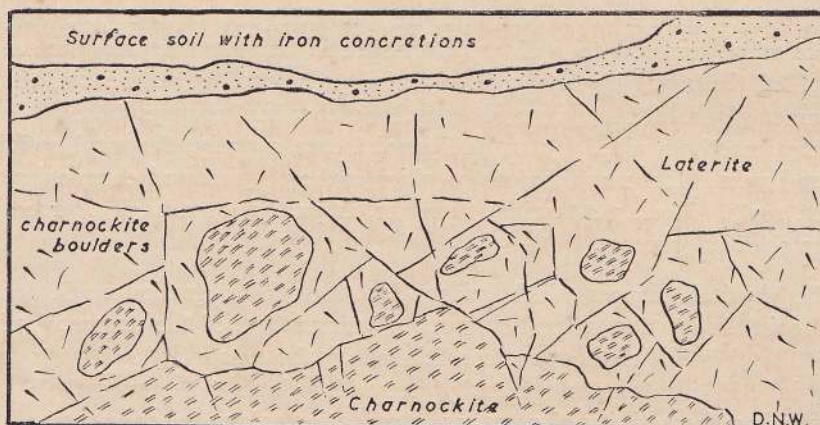


Fig. 1.—Sketch showing control of weathering by fractures and joints, and residual boulders in zone of weathering. (after D. N. Wadia).

### Weathering in the Dry Zone

In this zone, which includes the northern plains and the south-east portion of the Island, chemical weathering is subordinate to mechanical weathering.

The chief factor involved is the different rates of thermal expansion and contraction of the rock minerals due to the marked diurnal range of temperature. This results in the peeling off of thin concentric layers (or *Spalls*) of the exposed rock surface. It is sometimes aided by increase of volume due to hydration of the minerals. This process, to which the name *Exfoliation* has been given, accounts for the smooth rounded forms of the well-known Animal Rocks near Kurunegala, and for similar forms in other parts of the Dry Zone.

Chemical weathering in this zone is limited to the short rainy season which alternates with the long hot, dry season. The feldspathic constituents of the rocks break up into clay, sand and carbonates. Most of the carbonates are removed in solution and reprecipitated in the form of irregular concretionary nodules of impure calcium carbonate, to which the name *Kankar* has been given.

Some notes on weathering in certain small desert tracts of the north-west, as discussed by E. J. Wayland, appeared in Vol. I, No. 2, page 14 of the Bulletin.

### Weathering in Limestone Zones

The limestones of Ceylon are of two types, namely : (1) The Sedimentary Limestones of Miocene Age occurring in the Jaffna Peninsula and the North-West Coast ; and (2) The Crystalline Limestone of Pre-cambrian Age occurring in Central and South Ceylon.

Solution is the chief weathering process affecting the limestone areas, giving rise to slightly different residual products depending on their different chemical composition. The presence of carbon dioxide in rain-water enables it to dissolve out the calcium carbonate of the limestone, which it removes in solution as calcium bicarbonate, along joint and bedding planes. This gives rise to the familiar forms of sink holes, solution chambers (e.g. Puttur), and solution channels of regions.

The Miocene Limestone however contains minute traces of iron compounds in the original organic shell remains of which it is composed. These are insoluble, and the only action of water on them is to turn them into hydroxides. Their effect is to give the typical 'terra rossa' soil of the region the characteristic red colour.

The Crystalline Limestones which occur as narrow bands interbedded with the other Khondalite types, do not yield soil so readily as the Miocene. Being largely dolomitic, the residual clay is rather heavy because of its magnesian content.

## GEOGRAPHICAL RECORD

### LANDSLIPS IN THE KOTMALE AREA, CEYLON

Detailed surveys were carried out over the entire area affected by the officers of the Department of Mineralogy, some of which were made in conjunction with the Soil Conservation Officer and his staff.

The area damaged by slips falls into a well marked region defined by the Kotmale valley between Talawakelle and Ramboda, and includes 26 villages in about 120 square miles of area. In broad outline the geological structure of the area consists of a gently folded series of anticlines and synclines, with the main axes of folding in a rough north-west south-east direction.

The geological structure has had a pronounced effect on the topography of the area, and the dominant feature of the Kotmale Valley is the presence of very definite scarps forming prominent cliff-faces in the valley. Slopes of 50 to 60 degrees are common, and in exceptional cases slopes of even 80 degrees are present, such as in the Dombagastalawa-Belton scarp, the Kaipugala-Great Western scarp, and the Ramboda scarp.

The dominant rock types in the area are a series of pyroxene gneisses and granulites, with a well developed system of fissures and joint planes. The rocks themselves are highly metamorphosed rocks, but still show good bedding planes, representing the bedding planes of the original sediments. The main sets of joints are in the direction of dip and strike of the rocks. These pyroxene gneisses and granulites build up the main ridges and scarps, and interbedded with these are massive bands of quartzites, which represent metamorphosed sandstones, and subordinate bands of crystalline limestones. Well bedded massive quartzites, several hundred feet in thickness are seen on the Ramboda scarp, on the Katterawella scarp below Choisy, and on the Belton scarp. These rock types are completely crystalline and except where they are decomposed, they are completely impermeable, and have neither the capacity to hold nor to transmit water. Some circulation of water, however, undoubtedly takes place in the joint planes and fissures, and the evidence for this is in the existence of a number of springs.

Investigations revealed the occurrence of almost every type of slip from ordinary slumping of soil and talus or scree deposits, to rock falls of badly fractured and weakly joined rocks, failure of slopes due to under-cutting, actual earth-flows caused as a result of unprecedented rains to typical earth slips with well defined surfaces of sliding.

There is no doubt whatever that the immediate cause of the failure of the hill slopes in the Kotmale Valley was the unprecedented rainfall of August 14 and 15, 1947. Rainfalls of 16 to 18 inches were recorded at stations within the Kotmale Valley on August 14 and were followed by almost equal amounts on August 15 constituting one of the largest two-day falls ever recorded for the Island. The hitherto largest recorded daily fall in the area was 10.93 inches on July 2, 1892, nearly 35 years previous to the fall of the August 1947, rains. There is no doubt that the storm was of unusual intensity, and that it had exceeded all previous records within living memory.

This heavy rainfall alone could not by itself have caused such widespread and varied damage if conditions favourable for sliding had not been present in

the area. These conditions which favour sliding may be broadly divided into two distinct groups. The first category includes conditions inherent in the area and these relate to the geological, structural and topographical features of the area and over which man has no control. In the second category we have a set of conditions which have been imposed, so to say, on the area by the cumulative effect of various factors operating in different degrees and for varying periods of time. These factors can be directly attributed to the activities of man. They include the effect of forest fires, the removal of the forest cover on the upper slopes of catchment areas, inefficient drainage of steep slopes under plantation crops, and lastly the ponding of water for paddy cultivation on terraces above unstable slopes.

In a great majority of the slope failures investigated there were no definite surfaces of sliding, the failures being due to the swollen drainage of channels and streams draining the main scarp slopes. A study of the effects produced served to emphasise the very profound influence that water has played in the collapse of the hill slopes. Nearly all the features shown by the major slips in the Tispane, Meddecombra, Choisy areas of the Kotmale Valley are those characteristic of **erosion by water**.

A different phenomenon was observed in the village of Kotagepitiya, a village of about 600 inhabitants situated on a ridge on the north side of the east-west limit of the Kotmale Oya. This is a village situated on a terrace formed by the scree fallen from the main Peacock range. Several minor slips have taken place in this village, destroying large acreages of terraced paddy land which can all be related to drainage channels. But besides this the entire village is affected by **slow subsidence of the scree material** on which it is situated.

Nearly every house examined in this village showed the presence of cracks and all these cracks were found to extend in a rough east-west direction, *i.e.*, parallel to the river. According to the inhabitants of this village these cracks were not new and have appeared at various times after periods of heavy rains for over 10-15 years. As the cracks appear in the houses they are filled only to re-appear when the next heavy rains occur. Scree slopes or talus slopes are clearly unstable and it is quite evident that slow subsidence, however imperceptible, has been taking place over a period of many years. Along with the cracks appearing in the houses, fissures also appear in the ground and these have the same direction parallel to the river. These phenomena to which the inhabitants had been accustomed for several years, and to which they had certainly become indifferent assumed disastrous proportions after the storm of August, 1947. - Similar conditions were also found in villages like Watadora and Kadadora-pitiya and in all these instances the cracks whether they be cracks in the buildings or in the ground have always the same uniform direction, *viz.*, parallel to the river.

Here then we have a different phenomenon caused by the slow and almost imperceptible subsidence of talus and scree slopes. This phenomenon was not new and was only brought to a head and assumed disastrous proportions after the downpour of August, 1947. Some of these areas have not reached stability yet and further settling of these talus and scree slopes is likely.

A definite case of **slumping** was noted in the village of Kadadora where the surfaces of sliding were towards the river and the slumping has probably been caused by undercutting due to the river. Here again it is likely that slow slumping has been going on for years but it assumed disastrous proportions after the August rains, destroying the entire school, a building of substantial proportions. At the time of our visit the walls and foundations of the building which were left standing had very definite tilts of 4-6 degrees away from the river. The area affected was comparatively small and the road leading to Ulapane at a point opposite the school had subsided 24"—30" below its original level.

Slabs or blocks of loosely jointed rocks and rock debris may fall under their own weight under the action of gravity or assisted by flood waters precipitating over the cliff faces. It is this type of **rock fall or slide** from the Kaipugala scarp which practically destroyed the entire village of Meddacumbura at the foot of Kaipugala. The danger of rock fall from this cliff face has not abated and will no doubt continue with further violent storms. It is in fact just one of nature's forces for the levelling down of the inequalities in the landscape.

Nearly all the lower slopes of the entire valley of the Kotmale Oya are terraced paddy fields. Most of the damage caused to these fields, apart from the fields buried by the avalanches of rock and rock waste falling from the upper scarp slopes of the valley, is due to actual undercutting of the lands bordering the river during times of flood. This **undercutting action** has been **accompanied by typical slumping** such as the one at Kadadora and numerous examples can be seen in the valley. The extent of the undercutting action can be imagined when it is remembered that the river rose over 20 feet in places in the valley, destroying nearly every single bridge over it.

In the Kotmale Valley then we have a rather unusual combination of geological, structural and topographical features which give rise to a strong tendency towards slope failures. Over these features man has no control. But superposed on these are a different set of conditions for which man is responsible and which have increased the potentialities for slope failures inherent in the area. These are in the main—(1) Removal of forest cover on the upper slopes of catchments, and from the talus debris at the foot of scarp faces. (2) Inefficient drainage of steep slopes under plantation. (3) Ponding of water for paddy cultivation on terraces above unstable slopes.

Remedial measures should therefore be directed towards amelioration of the latter set of conditions. Further deterioration of steep unstable slopes by deforestation, chena firing, etc., should be arrested. Stabilisation of slipped areas and unstable slopes is achieved by proper land use and by soil conservation methods. Definite recommendations on these lines will be made by the Soil Conservation Officer, in view of the fact that remedial methods are almost entirely within his scope. The adoption of these remedial measures, it is confidently felt, will render a good portion of the Kotmale Valley more stable and safe during normal times and will minimize to a great extent the dangers to life and property from a repetition of such adverse meteorological conditions as the storm of August, 1947.

C. H. L. SIRIMANNE.

(Extracts from Chap. II. (Geology) of Sess, Paper XVII, 1954: "Report on Kotmale Landslips and adjoining River Catchments" by R. M. Gorrie).

PRESIDENTIAL ADDRESS TO SECTION OF GEOLOGY AND  
GEOGRAPHY, 41st SESSION, INDIAN SCIENCE CONGRESS

By DR. H. L. CHIBBER

1.—DRAINAGE PATTERNS IN INDIA

Dr. Chibber mentions two types of drainage patterns : (a) consequent, which are related to the uplift and the underlying structure of the country, (b) insequent, which bear no relation to the underlying structure of the region.

**Consequent Drainage Patterns :**

(i) *The Great Himalayan Rivers.*—From an investigation of the river terraces of these rivers Dr. Chibber has arrived at the conclusion that these rivers assumed their present form either towards the close of the Tertiary era or about the beginning of the Pleistocene period when the Himalayas had attained their present elevation.

(ii) *The Lesser Himalayan Rivers.*

(iii) *The Siwalik Rivers.*

(iv) *The Rivers of the Indi-Gangetic Plains, e.g. the Gumti, the Barna (Varuna), etc.*

*Radial Drainage.*—This includes the drainage systems of the highlands of Madhya Bharat (Central India), Mount Parasnath, Mikir Hills (Assam) and Mysore.

(i) *Madhya Bharat.*—The rivers descending from these highlands are the Chambal, the Sindh, the Betwa, the Ken, the Son, the Damodar, the Subarnarekha, the Mahanadi, the Wainganga and the Wardha. It is noteworthy that the Narbada and the Tapti flowing to the west belong to this system and by doing so they do not show any abnormal behaviour.

It is also noteworthy that some of the tributaries of the Yamuna, *viz.* the Chambal, the Sindh, the Betwa and the Ken, are older than the main river, *i.e.* the Yamuna of today. Likewise, the Son is older than the Ganga in which it discharges its waters.

(ii) *Mount Parasnath.*—The drainage of Mount Parasnath, 4,550 ft. above sea level, in the Hazaribagh district of Bihar furnishes a classical example of radial drainage.

(iii) *Mikir Hills, Assam.*—The drainage represents another example of radial drainage and has been discussed in detail in the address.

(iv) *Mysore.*—The rivers of Mysore constitute again a radial pattern which has been described by Dr. C. S. Pichamuthu. The drainage of the Shali peak and the Ranchi plateau also reveal the same pattern.

*Centripetal Drainage.*—The drainage of the Katmandu Valley in Nepal furnishes a very interesting instance of centripetal drainage. The Bagmati represents the main river which receives tributaries from all directions and one of the tributaries, the Nakhu Khola, runs in a direction counter to the main river before joining it. The drainage of Kashmir is also of the same type. Both these systems have been discussed in detail.

*Dendritic Drainage.*—This pattern is exemplified in many parts of India, e.g. the region near Dehra Dun furnishes a very good instance, but the ravine lands of the Yamuna, the Chambal, etc., represent a classical example of this type of drainage.

*Drainage of Uniclinal Structure.*—The plateau of the Vindhya (Mirzapur district) with its scarp exceeding 1,300 feet above the sea level and about 6 miles south of Robertsganj furnishes a good example of this interesting type of drainage. The plateau slopes very gently to the north to Rajghat, 550 feet above the sea level, south of Mirzapur.

The drainage of Peninsular India represents this type of drainage on a continental scale. The rivers take their rise from near the edge of the scarp of the Western Ghat and flow on to the east. They also furnish example of parallel drainage and wherever centrally elevated regions occur, radial patterns have been formed.

### Insequent Drainage Patterns :

(i) *Antecedent Drainage.*—The familiar examples of this type are the Brahmaputra, the Sutlej and the Indus. During his exploration of the Tehri Garhwal Himalayas, Dr. Chibber found that the Jahnvi or the Jadh Ganga which meets the Bhagirathi near Bhaironghati below Gangotri furnishes another example of an antecedent river which has its source in Tibet.

(ii) *Super-imposed Drainage.*—Examples of this type of drainage are common in Peninsular India. The original drainage may have been established in the Deccan Trap which by its erosion is now super-imposed in the Archaen rocks.

(iii) *Thrust Super-imposed.*—This is a new type of drainage which Dr. Chibber has observed near Simla. The region is composed of the Shali series probably of Krol age which are overlaid by the Tertiary rocks. The whole area was covered by the Older Chail series with a thrust. The drainage, which was originally established on the Older Chail rocks, was by their erosion super-imposed on to the younger Tertiary rocks and ultimately on to the underlying Shali series. It is biserial in character with regard to its super-imposition. Examples of ordinary super-imposed drainage are known from other parts of India and elsewhere but this thrust super-imposed drainage is a new discovery.

(iv) *Migratory Type of Drainage.*—Although practically all the rivers flowing in the Indo-Gangetic plains exhibit this characteristic of drifting to the west, the Kosi which has shifted to the west by about 75 miles during the last 200 years is a classical example. Dr. Chibber has published a detailed account of the phenomenon of westerly drift of the rivers in Northern India and Pakistan. This drift is attributed to secular causes and the law applicable to winds and ocean currents holds good in the case of river currents also.

## II.—DEVELOPMENT OF LANDFORMS IN THE HIMALAYAS

Dr. Chibber discusses in detail the five factors, viz., structure, process, stage, geology and relief, which have influenced the formation of the Himalayan landscape. The landforms developed in the granite and the quartzites are, however, altogether different from those developed in the schists, phyllites and slates.

For purposes of study, Dr. Chibber classifies the landforms as under :

- (i) The Siwalik Range with a maximum elevation of 4,000 feet above sea level.
- (ii) The Middle or the Lesser Himalayas having a maximum elevation of about 12,000—15,000 feet above sea level.
- (iii) The Great Himalayas with an average elevation exceeding 20,000 feet above sea level.

*Structure.*—The structure of the Himalayas is very complicated. The Himalayan nappes have been pushed forward to considerable distances and thrust over other rocks, but the dip-slope and escarpment feature, so characteristically observed in the Siwalik Range, is also to be observed in the Middle as well as in the Great Himalaya. Dr. Chibber observed this feature in the Tehri Garhwal Himalaya. The same feature is observed in the Pir Panjal Range and also in the Great Himalaya including Mount Everest, etc.

*Process.*—In the Siwalik Range the action of rain and running water are the dominant agents of denudation, especially in carving out the ravines on the scarp side. In the Middle or the Lesser Himalayas the action of frost also is responsible for developing talus and talus streams. As a result of jointing and gravity, rockfalls also occur, but they are more characteristic of the Great Himalaya.

*Stage.*—The study of river terraces of the Bhagirathi, the Yamuna and other rivers has revealed that the base level conditions are reached when the region undergoes rejuvenation and other subcycle is initiated and vertical corrosion commences again. In some places 6-7 such terraces were counted, but 3-4 are common. Dr. Chibber concludes that the Himalayas underwent intermittent uplift during the Recent Period.

*Landforms of the Siwalik Range.*—A detailed study of the development of the landforms in the Siwalik Range adjoining the Doon Valley reveals in a characteristic manner the dip-slope and escarpment feature. The former is covered with dense sal (*Shorea robusta*) forest, while the much steeper scarp face is highly ravined. The highest point, Amsot, is 3,140 feet above sea level. The maximum width of the Siwalik Range in this region is about 10 miles. Its trend varies from W.N.W.—E.S.E. to N.W.—S.E. In places the range is traversed by longitudinal valleys.

The Siwaliks on the escarpment side form high cliffs with sharp peaks. From the peaks descend spurs which are really knife-edged. In places the form of the peaks is pyramidal, conical and almost needle-like. The Siwalik Range shows a beautiful serrated crest.

*Landforms in the Middle Himalayas.*—As a result of normal erosion, deep gorges have developed in this region in hard rocks like the granite and the quartzites, while in the schists and phyllites broad open valleys are formed. The rivers descend through transverse and longitudinal valleys. In the region of the softer rocks river terraces commonly occur. The hanging valleys and waterfalls are also formed, but they are even more characteristic of the Great Himalaya. Interesting incised meanders have also developed. They are V-shaped, U-shaped

and inverted U-shaped which may be narrow or acute or may be broad. The talus and talus streams commonly occur which tend to grade themselves. Landslips, landslides and rockfalls commonly occur in this region as also in the Siwalik Range. The small tributary streams of the Bhagirathi, etc., especially those which have steep courses, have well-marked alluvial fans.

*Landforms in the Great Himalaya.*—The elevation being greater in this region, precipitation in the form of snow is much greater and consequently the action of snow and ice is very characteristic. Glaciers, both longitudinal and transverse, carve out typical glaciated topography. In this region glacial lakes are common. Rock basins, originally carved out by former glaciers, may occur at lower levels than where glaciers descend today. This indicates the extent of recession of the former glaciers. The hanging valleys and waterfalls are more common in this region and some of the waterfalls may be 200 feet or even more in elevation. The action of frost is very severe and where the rock is jointed and the joints dip with gravity, rockfalls, sometimes huge in size, are very common.

This region comprises an endless vista of mountains or a chain of peaks, about 20,000 feet or more in elevation above sea level and not infrequently culminating in a majestic summit. The peaks comprise massifs, great rock-peaks, pyramidal peaks, white domes or beautifully shaped snow-cone summits. There may be twin peaks or the main peak may have its satellites. The peaks are connected by sharp or knife-edged ridges with cols, 18,000 feet or more in elevation. At some places occur the overhanging rock with snow-fluted precipices dropping several thousands of feet. The Nanga Parbat rises more than 20,000 feet above the Indus Valley. The slopes are not only precipitous in places with crevices and chasms, but ice walls, ice falls, rock walls, etc. are common.

The lower regions represent a land of glaciers with their crevasses, a series of surface moraines, etc. In places an incredible quantity of rock may cover the ice giving it an appearance of a glacier of rocks. From their snouts issue forth streams which may follow a longitudinal trend for some distance but then pierce the Great Himalaya and carve out deep and constructed gorges. Thus, the action of frost and the work of snow and ice are seen at their best in this region.

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1. **Manuscripts** should be typewritten on one side of paper only, with double spacing and wide margins, and should as far as possible be original copies.

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- FARMER, B. H., 1951 ... Some thoughts on the Dry Zone. Bull. C.G.S., Vol. VI, pp. 165-178.  
LEITER, N., 1947 ... Denudation chronology and the drainage pattern of the Central Massif of Ceylon. Bull. C.G.S., Vol. II, pp. 64-69.  
....., 1949 ... Geographical Study of the Nitre Cave District. Bull. C.G.S., Vol. III, pp. 61-72.

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