SOILS AND LANDFORMS

By G. W. A. SPARROW

This study presents some rather neglected aspects of soil-landform interrelationships and in doing so draws from the author's fieldwork not only in Natal but also from various parts of the world. Bearing in mind that the subject belongs to a relatively new sphere of research, some of the conclusions put forward are admissibly tentative.

Past Research

Before the scientific era in agriculture, farmers must have been aware that changes in topography were associated with corresponding soil differences. Unfortunately, although early soil scientists did much to show that pedogenesis was directly related to climate and parent material, they paid scant attention to its influence by topography until the nineteen twenties, when for example, the catena concept was proposed.

Little real progress was made until the last decade, when Butler (1959), working in Australia, formulated a sound basis for the study of topographic influences on soil development. His published work is considerable in amount, but his main findings may be summarised as follows:

1. Pedogenesis is controlled by the four variables of climate, parent material, natural vegetation and landform. For specified conditions of these, soil development takes place at a given rate, which will only be changed by a variation in one or more of the variables.

2. So long as the above variables remain constant in any particular case, stability prevails and eventually a mature soil forms. Should this stability be disturbed, an immature soil results. By far the most common cause of instability results from changes in topography.

It will be seen that Butler's main thesis concerns soil stability, especially as related to topographic development. In order to understand this better, a brief summary of "landform dynamics", or geomorphology as it is known, is given.

Landforms

No landscape is completely lifeless. Streams will always erode and deposit material, chemically charged water will dissolve rocks, debris will creep down slopes, and so on. This realisation that all landforms are dynamic rather than static, is fundamental to the understanding of soil-landform relationships.

Most soil forming material is derived from the disintergration of rocks by a process known as weathering. This is a combination of mechanical agents such as expansion and contraction, and chemical such as solution. The former agents tend to dominate in dry areas, the latter in humid. Weathering takes place far more rapidly in soft rocks such as Ecca shale, than in resistant types such as Table Mountain sandstone. Thus it follows that the depth of weathered material is generally greater over soft rocks than over hard.

As streams cut downward, they form valleys. When relatively immature, the slopes bounding these valleys are steep; when mature they are gentle. Because most landscapes are composed of slopes, it is essential to have a means by which their various elements may be classified and described.

The most practicable method is that of King (1963). His first classification (Fig. 1a), shows a mature slope in which all elements are fully developed. While there is naturally some variation in each element with differences of rock type and climate regime, they can usually be identified fairly easily. The second case (Fig. 1b), depicts a more senile slope form where some of the elements vanish leaving the familiar convexo-concave form which, in its final stages, may have such low angles as to be scarcely recognisable as a slope.

On the relatively level upper surfaces above the slope, conditions for soil formation are stable and pedogenesis has taken place over a considerable period. Soils will therefore exhibit mature characteristics with well developed horizons. As soon as the surface begins to grade into the waxing element, however, stability diminishes due to gravity-induced movement of material, until it is non-existent at the free face. The soil movement on this waxing element takes many forms. At times it is seen as a progressive thinning of horizons while at others, it gives rise to small revets which move downslope. While natural vegetation impedes this movement to some extent, it is rarely able to stop it completely and thus any cultivation on the waxing element may lead to serious erosion.

The free face below the waxing element may safely be ignored for, due to the rapidity of weathering, little soil ever forms. The talus slope below, however, shows marked soil development. Firstly, it is a zone of debris accumulation, the broken material from above providing a steady supply of soil forming material. Secondly, most of this talus is in almost constant movement down the slope, thus it is a zone of low stability and carries generally immature soils having indistinct horizons.

The above examples give some idea of soil development on slopes of relatively steep angles such as those seen at Drummond overlooking the Umgeni River valley. Many slopes, however, have much lower angles and are of interest as they occur most commonly in farming areas. They fall into the senile category (Fig. 1b). In this second group, the waxing and talus slopes have coalesced, completely obliterating the free face. Because of lower slope angles, soil movement is much slower and soil thicknesses are generally greater. While the effects of soil movement may still be discerned on such slopes, they are far less prominent. In addition, the effects of natural vegetation in impeding this movement are far stronger and soil erosion is much less prevalent.

FIGURE 1A : MATURE SLOPE FORM

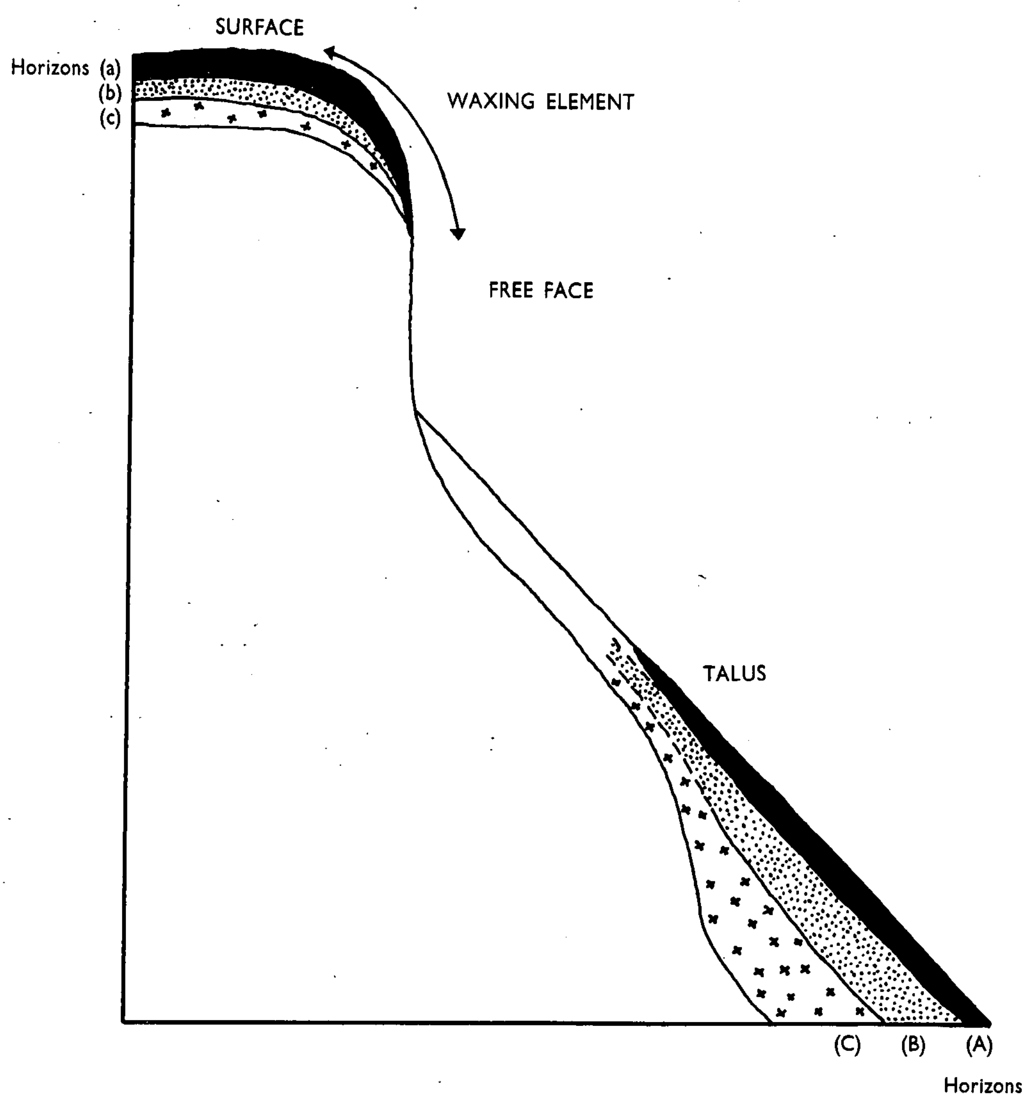
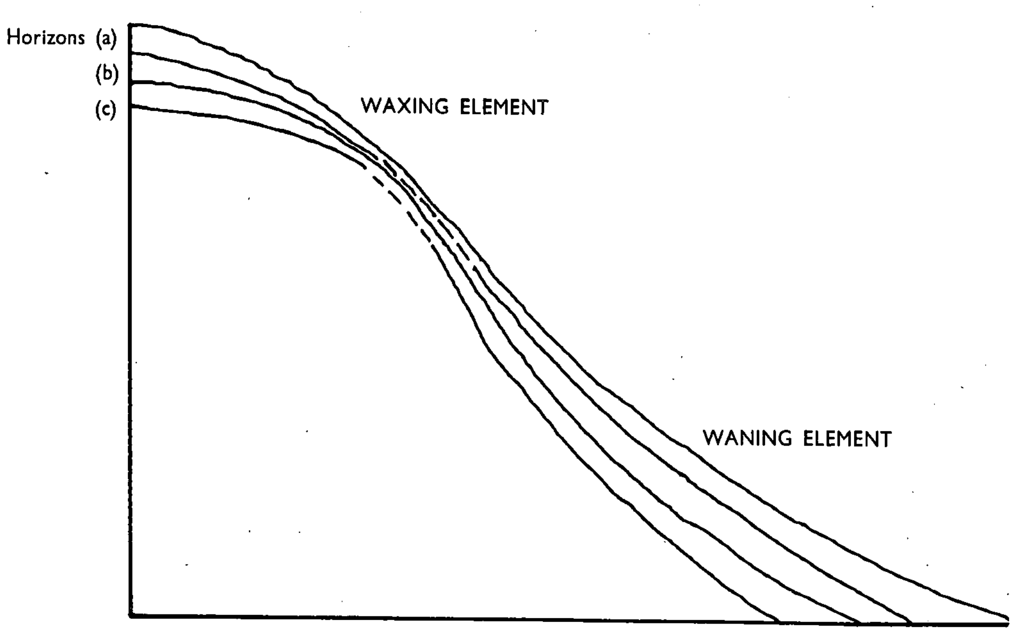


FIGURE 1B : SENILE SLOPE FORM



Field Examples

The above account has been mainly along theoretical lines. The following examples attempt to show how the principles discussed may be applied in the field.

General Slope Development (Fig. 1a)

The "basic" example earlier quoted for general slope development is very typically displayed in granite country some 350 miles to the north of Sydney in the New England region of Australia, where the soils developed are mostly of a podsolised type. This overall soil type, developed on a porous parent material in association with well developed slopes, seems to show the effects of movement and horizon thinning particularly clearly, hence the reference to it in this paper as a type example.

Unstable Face — Drakensberg Areas Sani Pass (Fig. 2a)

This is an example of soil development in a highly unstable area. Due to extremely active cutting down of valleys by streams, slopes are steep and very mobile. As a result, soils are immature and consist of little more than ill-sorted rock fragments. Vegetation finds difficulty in colonising these slopes and thus exerts a negligible influence impeding downslope movement, a factor well in evidence by the almost total absence of soil on the waxing slopes.

Multiple Single Slope Form — Gun Drift near Harding, Natal (Fig. 2b)

The area in question consists of a rolling plateau of some 2,000 feet altitude through which the Umtamvuna River has cut a valley 700 feet in depth. Bedrock comprises Lower Ecca shale that has been intruded extensively by sills of dolerite, these latter forming the steeper slopes of the area due to their superior resistance. Two such sills occur in the area quoted, an upper and a lower, giving rise to a multiple slope form.

The upper sill forms a broadly convex waxing element at the slope summit and has weathered to form red brown ferruginous clays. Soil thickness on this convex slope rarely exceeds 6 in. and no trace of horizon development has been noted. Free faces occur occasionally below the waxing slope, but the general pattern is that of a smooth grading of waxing into talus-waning elements, with a corresponding thickening of soil to three feet. Maximum slope angles are rarely more than 25° and the lack of visible erosion suggests a good adjustment of soil and vegetation to topography.

Although Ecca shales form the bedrock below the waxing slope, the soil parent material is completely dominated by red ferruginous clays derived from the overlying dolerite.

Five hundred feet below the slope summit, a second sill of dolerite occurs and forms a conspicuous bench which extends considerable distances upstream and downstream. Red-brown ferruginous clays form the dominant soil material, but are frequently mixed with grey-black river clays and lenses of stony material, both of which suggest that this bench was formerly a floodplain in the river. Soil depth is often as much as twelve feet and is assumed to be due to the combined deposition of talus material and old river plain deposits.

The edge of this bench marks the commencement of the lower slope, the waxing element of which is strongly convex and shows marked soil thinning. Below is a steep cliff-like free face of dolerite which drops 100 feet to the river. Talus below this free face is intermittent in occurrence due to its removal by river action.

Multiple Development — "The Glen"—near Franklin, Cape Province (Fig. 2c)

So far, only simple slopes have been treated in order that basic soil-landform relationships may be easily understood. A cross-section of an entire farm is now given, for it is this type of relationship that normally confronts the soil scientist or farmer.

The property in question is situated in the east of the Bokkiesberg range in East Griqualand, some ten miles to the south-west of Franklin, and consists of a basin of 5,500 feet altitude bounded by hills rising to 7,000 feet on all but the south-eastern side. These hills are formed of Middle Beaufort sandstone, liberally intruded by sill of dolerite and gabbro. The basin drained by the Vlakspruit, is cut on the softer shales and sandstones of the Lower Beaufort series.

At the southern end of the basin, a thick dolerite sill forms a hill mass rising some 500 feet above the valley. While red-brown ferruginous clays form the soil material here, the soil environment is far less stable than in any of the previous examples and large patches of the extensive waxing slopes are completely devoid of soil cover and several areas of broken rock occur. Shallow skeletal soils are found between these rock fields in pockets and rarely exceed depths of a few inches.

A similar dolerite sill forms the hill mass bounding the northern flanks of the basin and while soil development is superficially similar, the pockets between rock outcrops are more numerous and soil depths are generally greater, often reaching two feet.

Within the basin itself, soils are derived from both dolerite and Beaufort shales, the former comprising red-brown clays, the latter light grey sandy clay loams. This second division normally extends to depths of up to one foot and overlies strongly weathered yellow-brown shale. Slope angles do not exceed 7° and this seems to account for the absence of horizon thinning.

Several streams within the basin suffer from impeded drainage due to various causes and this is responsible for the development of gleyed profiles locally, a typical example consisting of about 12 inches of grey sandy clay loam underlain by a light grey medium clay with abundant rust coloured mottles.

Observations on some soils of the coastal sugar belt

It has been implied so far how soil, vegetation and landform are constantly adjusting themselves under a climatic stimulus towards more stable arrangements. In the relatively high-altitude examples already quoted,

FIGURE 2A : UNSTABLE FACE (SANI PASS AREA)

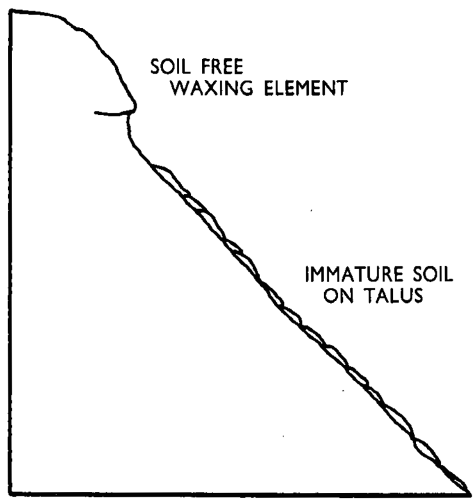


FIGURE 2B : MULTIPLE SINGLE SLOPE FORM (GUN DRIFT NEAR HARDING)

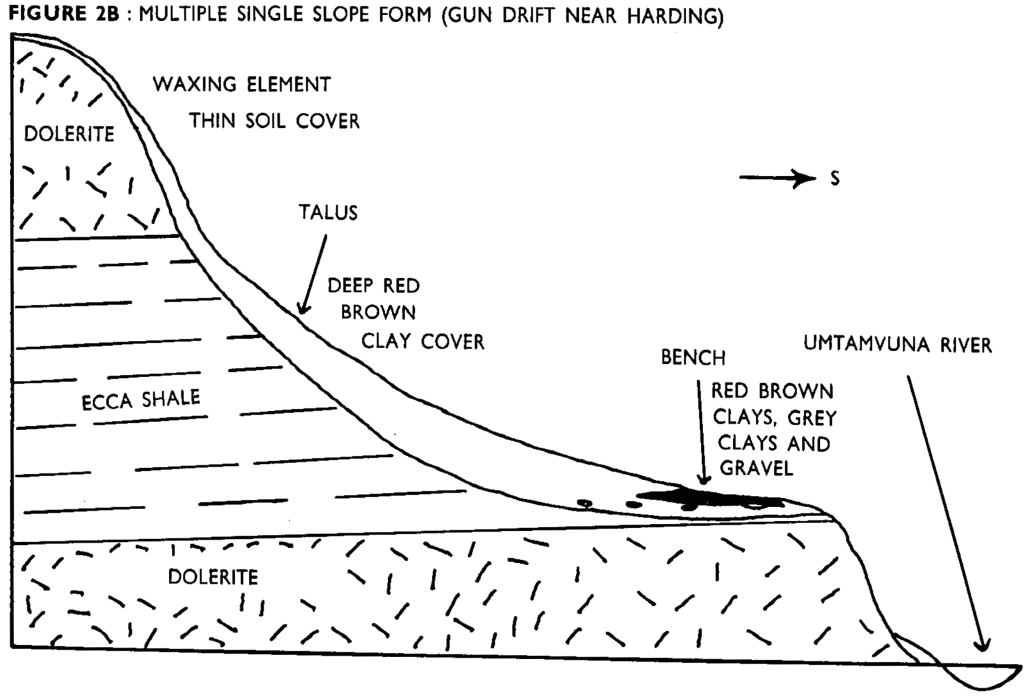
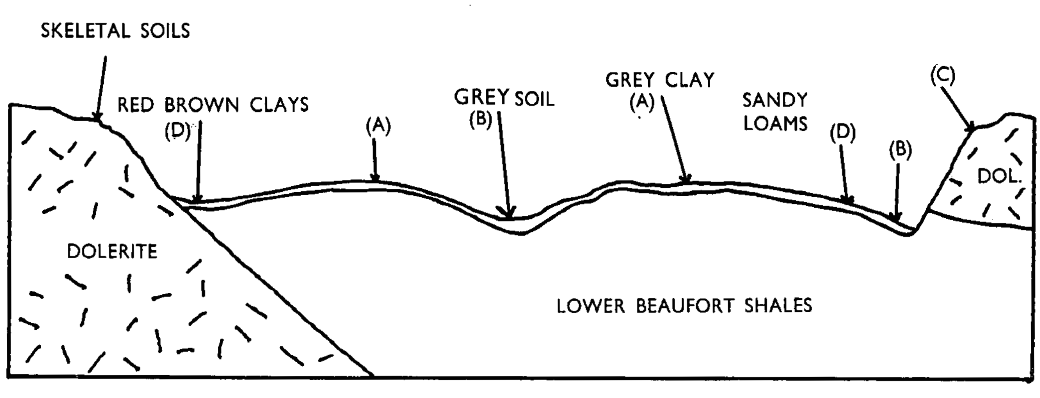


FIGURE 2C : MULTIPLE DEVELOPMENT ("THE GLEN" NEAR FRANKLIN)



vegetation is generally a type of grassveld which, with the severe climatic conditions encountered (e.g. frost, droughts, etc.), is not permitted to exert such a strong binding influence on weathered material as does forest. The balance between stability and instability is therefore somewhat delicate and consequently differences between stable and unstable areas is strongly marked. Such areas are thus excellent for initial study and establishment of principles. Much of the sugar belt lies in a region of more humid bush and coastal forest where natural vegetation does not suffer many hazards, thus adjustment to the environment can be much more rapid. The impeding power of roots is very effective in restricting downslope movement of soil material, thus several relationships easily seen in other areas are difficult to distinguish here.

One of the best examples of this well established adjustment is seen in soils of the Williamson series. The general profile shows 15 inches of light grey fine sandy loam overlying 3 feet or more of yellow-brown strongly weathered parent rock, in this soil series Dwyka tillite. It occurs on slopes of angles often as great as 50°, but shows surprisingly little variation in thickness apart from some slight reduction in a few summit areas.

Both Glenrosa series on granite and Cartref series on Table Mountain sandstone also show negligible differences in soil thickness. There are, however, one or two instances of soil movement, as for example in soils of the Mayo series.

This series developed from a special type of foliated granite occurs in strongly dissected hill country, e.g. in the Ifafa River area, having an available relief of 500 feet. Slopes are convexo-concave in form, although a few free faces occur intermittently. Slope angles reach a maximum of 50°.

The generally highly stable soil environment which obtains in the sugar belt, extends from the coast inland to altitudes of some 1,300 feet, above which horizon thinning, active soil erosion, etc. are again prevalent on slopes. This alteration in stability seems to be less a function of parent material than of climate and natural vegetation.

In conclusion, it appears that soil-landform relationships follow "classic" patterns in most parts of the country, but that the soils of the sugar belt in Natal conform only to a limited degree. The reason for such limited conformity poses a problem, for, assuming that the sugar belt topography was formed by Recent and Quaternary incision, why is it that such a negligible amount of soil movement has taken place? This phenomenon is repeatedly seen throughout the lower altitudes in the sugar belt and has been confirmed by numerous workers, but no satisfactory explanation has yet been advanced.

Summary

This paper demonstrates interrelationships existing between soil development and landforms. The background of research in this subject is briefly outlined and two "standard" examples quoted. Actual field examples in ascending order of landform complexity are presented to illustrate landform relationships.

The exceptionally stable soil environment of the main Natal sugar belt is discussed.

References

Butler, B. E. Periodic Phenomena in Landscapes as a basis of Soil Studies. C.S.I.R.O. Soil Publication No. 14, Melbourne, 1959.

King, L. C. South African Scenery. Oliver and Boyd, Edinburgh, 1963, pp. 41-48.

Dr. Davies: This paper is a re-evaluation of the principles of slope-soil relationships and though it presents nothing startlingly new, it is a welcome contribution from Mr. Sparrow, particularly as it seems to keep our attention focused on fundamentals.

The author refers freely to the work of Butler in Australia. I know very little of Butler's work, though I find interesting his concept of stable environment as one where soil forming variables remain constant and his other concept, that an unstable environment is one where the variables are subject to change.

I find Mr. Sparrow's analysis of soil type conditions in Natal rather elementary in some respects and insufficiently critical. I would like the author to elaborate, for example, on the idea of cyclic formations of soils with reference to Natal and attempt to place the factor of changes in topography (which are apparently the main causes for instability) in its perspective in relation to other soil forming variables. Could Mr. Sparrow not also indicate the degree to which changes in stability and instability in environment are apparent in our South African scenery, and also the state of cyclical development reached?

Certain quantitative measurements could have been given in addition to the few examples in the paper. What of the significance of regional or local differences in the qualities of the variables in cases where slopes might be similar, but where differences in the thickness of the soil profile in particular may be observed? For example, soil thickness on steep slopes on Table Mountain sandstone of different compositional characteristics. On some slopes the soil may be very thick or deep, whereas on other similar slopes of T.M.S. the soil may be very thin.

I would have liked the author to have elaborated further on the problem of soil stability on the coastlands.

This he will no doubt do at a future date, applying a more quantitative approach to these very interesting problems of soils and landforms.

Mr. Sparrow: My paper invited criticism and Dr. Davies has supplied it. In thanking you, Dr. Davies, I would like to make the assurance that I certainly intend carrying on with the study, particularly in respect of the stability of coastland soils. The present paper is not intended as a treatise, but primarily to stimulate ideas. If I have succeeded in doing that at this stage, I am large satisfied.

FIGURE 2D : SUGAR BELT SOILS SHOWING DEPTH CHANGES

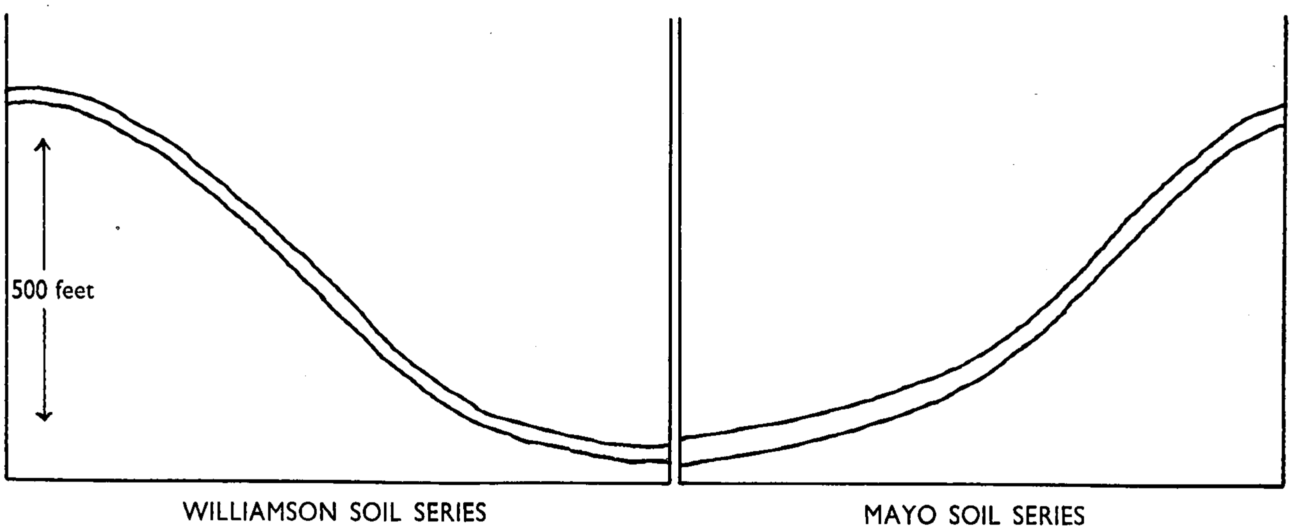


FIGURE 3 : CROSS SECTION OF SOUTH EASTERN NATAL