SOIL SURVEY: WITH SPECIAL REFERENCE TO THE NATAL AND ZULULAND SUGAR BELT.

By F. J. ROSENSTRAUCH.

Division of Chemical Services, Department of Agriculture and Forestry.

As far back as December, 1924, and February, 1925, the soils of various sites proposed for the Experiment Station of the South African Sugar Association were reported on by C. Williams, then lecturer in chemistry at the Cedara School of Agriculture. From this it is evident that fourteen years ago the importance of a study of the soil profile was recognised.

It was, however, not until late in 1929 that the Division of Chemical Services was first approached in connection with some form of soil survey of the sugar belt. From the very outset the necessity for close co-operation between that Division and the Experiment Station was emphasised. The soil survey staff of our Division was so fully occupied on urgent Government irrigation projects, that nobody could be detailed for work in the sugar belt until 1936.

With the co-operation of Mr. Beater, of the staff of the Experiment Station, I carried out a very extensive soil survey of the Experiment Station, comprising 86 acres, during October, 1936.

It was then hoped that a fully-equipped soil survey party would be made available by the South African Sugar Association in 1937 to carry on with a detailed survey of the sugar belt. It was agreed that our Division would supply an officer to co-operate in this undertaking. Unfortunately this suggestion did not materialise and the programme for 1937 had to be revised. The sites of all the co-operative field trials of the Experiment Station were investigated in detail, together with a less detailed survey of the area in the immediate vicinity of each plot, i.e. the farms on which such trials are situated.

Again Mr. Beater and I co-operated in the soil investigation, while a surveyor of the Division of Chemical Services was responsible for the location of all surface and topographic data. This investigation took us from the coast to about 20 miles inland, and from Umzinto in the south to the Umfolozi Flats in the north. The soil survey of some eleven farms was completed, together with the field plots of Natal Estates and some on Tongaat Estate. The work occupied some six months, and it was hoped to have a comprehensive report ready in time for presentation to this conference. Other duties have intervened and kept me too occupied to realise this hope.

After consultation with the Director of the Experiment Station and Mr. Beater, I am endeavouring to meet the case with a popular talk reviewing the results of the survey, in which I hope to touch on the points to be later discussed in our final report.

Before proceeding, I feel it essential to give a brief resume of the more recent advances of pedology and soil classification and mapping. In doing so we have to answer the following questions :—

(1) What is soil?
(2) How is it formed?
(3) What system of classification can we apply to differentiate soil groups?

Most of the quotations given in the following discussion were obtained from "Pedology," that excellent work by Jacob S. Joffe.[1]

1.—What is Soil?

The older conception was that the soil is a dead mass consisting of coarser and finer material mineral aggregates containing the decomposition products of plants and animals, through which the moisture and nutrients necessary to support plant life are supplied. The soil was defined by various workers as :—

(1) "A mixture of decayed rock and organic matter," or
(2) "Soils are broken and decomposed rock."

It was Dokuchaev, leader of the Russian school of thought in soil genesis and classification, who first formulated the theory that the soil is not a dead, inert body, but a living dynamic entity. He appreciated the complex natural agencies responsible for the processes of soil formation and recognised their superior forces, as being more capable of influencing the type of soil formed than the parent rock material from which the soil arose, in that its distribution is governed by natural laws in the same manner as are living organisms. He stated: "If we know the factors of soil formation we are able to state in advance what the soil must be like." In his writings Glinka continually refers to the soil as a "living" body. The following extract from his works is but one example: "This plot of soil has been within recent years so thoroughly dug over by rodents that there is, one might say, no '*living*' spot left in it."

Joffe in his book on Pedology quotes and criticizes definitions of soil by various writers as untenable, on the grounds that all the contributory factors (intrinsic and extrinsic) are not simultaneously taken into account. He finally suggests the following definition: "The soil is a natural body, differentiated into horizons, of mineral and organic constituents, usually unconsolidated, of variable depth, which differs from the parent material below in morphology, chemical properties and composition, physical properties and constitution, and biological characteristics."

2.—How is Soil Formed?

According to Joffe, "the evolution of the complex constitution and habitus, or general appearance of the soil in relation to the natural laws responsible for its origin is known as 'soil genesis.' It is controlled by a series of natural forces, guided by definite natural laws, which find expression through the factors known as 'soil formers'."

These processes are genetically related to weathering, which geologically is responsible for the mantle rock of the earth's crust as distinct from the bed rock. Soil formation and weathering are not identical processes, and it would be well to consider the former as being a counter-reaction to the latter. Both processes have been mutually and simultaneously at work in creating the soil body.

The processes of weathering can be divided into (1) physical, (2) chemical, and (3) biological. Physical weathering is the process of disintegration of the parent rock into finer aggregates which in composition remain identical to the parent material. Contraction and expansion due to temperature changes, accentuated by differential expansion and contraction due to mineralogical complexity of some rocks, constitute vital forces of disintegration. To these must be added, amongst others, the erosive action of wind and water, force exerted due to expansion of freezing water, and the scouring and crushing effect of glaciers.

Chemical weathering involves the decomposition of the rock and is essentially evident in two phases:—

(*a*) the disappearance of certain minerals, and
(*b*) the formation of secondary products.

Chemical decomposition is subject to the following principal processes of—

(1) oxidation,
(2) hydration and hydrolysis,
(3) carbonation,
(4) solution, and
(5) deposition.

These chemical processes are well known to all of us and time does not warrant further discussion of them.

Chemical weathering is influenced by various extrinsic and intrinsic factors, such as climate, type of rock, its capacity for heat absorption, its structure and constitution.

The climatic influence is very marked, and it is on this influence that the Russian system of soil classification is ultimately based. Differentiation is made between cold, temperate, warm and moist, warm arid, and arid temperate climates.

Biological weathering consists of physical and chemical weathering through biological agents. Roots of trees and micro-flora enter cracks and crevices, causing disintegration of the rock. Chemical weathering is stimulated by carbon dioxide and weak acids excreted by the roots. Micro-organisms derive energy from inorganic constituents and carbon from the carbon dioxide of the air. They also directly attack and decompose the silicates, etc.

So much for the three major processes of weathering, and I now wish to briefly refer to the process of soil formation, where two distinct phases are again recognised: (*a*) Creation, destruction and accumulation of organic matter, and (*b*) continuation of the weathering processes, (1) physical, (2) chemical, and (3) biological. The second phase, i.e. the continuation of the weathering processes, produces the mass of the soil body, the raw material upon which the first phase, i.e. the organic matter, reacts to gradually produce the ultimate complex natural object, the soil.

The multiple activities of different factors which go to build up the soil were called by Dokuchaev the "soil formers," of which two types are identified with each of the phases of soil formation:—

(1) Passive soil formers,
(2) Active soil formers.

The passive soil formers play an indirect role and comprise—

(*a*) the parent material,
(*b*) the topography, and
(*c*) the time, or age of the land,

while the active soil formers supply the necessary energy to furnish the active reagents for the processes of soil formation:—

(*a*) The climate, which is further subdivided into (1) rainfall, (2) temperature, (3) humidity and evaporation, and (4) wind.
(*b*) The biosphere, consisting of plant and animal life (macro as well as micro).

Time does not allow me to discuss each of these factors and their influence in detail.

3.—What System of Classification can we apply to differentiate Soil Groups?

This leads us to the processes of soil formation when organic and inorganic products undergo differentiation, into definite horizons, the complete succession of which down to the parent material constitutes the "soil profile." We have to differentiate between the "broader fundamental" and the "specific" soil forming processes. The former are universally active, while the latter bring out differences in the individual genetic horizons and reflect results of variations in physical, chemical and biological factors at work in different soil zones.

We find several more or less different systems of soil classification adopted. Chief amongst these are the following, which involve the study of the soil profile from three points of view :—

(*a*) The parent material—petrogenetical basis.

(*b*) The climate—the active agent reacting on the parent rock—the climatogenetical basis.

(*c*) The vegetation—agrological basis.

The Russian school, under Dokuchaev and later Clinka, has brought soil classification on the climatogenetical basis to an advanced degree and their terminology has been generally accepted and adopted. In a Technical Communication[3] of the Imperial Bureau of Soil Science, is given a summary of the major types as recognised by the Russian school.

The danger of blindly following any one system of soil classification cannot be sufficiently stressed. Continuity of any one zone is often broken by local factors such as topography, moisture conditions, composition of parent material, local climate and vegetation. We must differentiate between na ture and immature profiles, as passive soil formers predominate in the latter. Vegetation plays an important role and is often included in the nomenclature of the different soil zones. As proof of vegetative influence a case is cited where a chernozem soil, when planted to forest, gradually degraded and showed definite tendencies to podsolic formation.

The Division of Chemical Services has approached the mapping of the soil of irrigation schemes and projects chiefly from the utilitarian point of view and studied the characteristics of the profile from the point of view of its potentialities. Soil reaction, alkali content, texture, structure, depth (taking due account of interfering layers), moisture conditions, and root development are taken into account in an endeavour to assess the ability of the soil to support plant life. Typical samples are subjected to chemical analyses. At the same time an attempt is made to give a scientific explanation of the origin and history of formation of the various types and fit this in with the universal system of soil classification.

In these soil surveys for irrigation projects the soil is finally mapped and graded into six grades of so-called "irrigability." We map separately soil reaction (pH), soluble salt content (brak) and soil types (profile), and arrive at the final irrigable value by superimposing these three maps. Previously utilization and surface (texture and colour) maps were also made, but these have been discontinued in routine surveys except where they may be of any special significance.

Mr. C. R. van der Merwe of our Division has found during his reconnaissance soil surveys of the Union that our soils can be classified into climatic groups. Several groups have already been recognised and studied physically and chemically in some detail. A provisional soil map of the Union has been drawn up (which was exhibited at the Empire Exhibition in Johannesburg) and is gradually being completed as more information becomes available.

THE SOILS OF THE SUGAR BELT.

In the work thus far undertaken in the sugar cane belt, Mr. Beater and I have followed similar lines. We have endeavoured to group the soil in definite types, at the same time taking due account of the utilitarian side of the problem.

Except for the belt running more or less parallel to the coast and commencing some distance inland at an altitude of some 2,000 feet (the so-called "mist belt"), the climate throughout the cane belt, from a point of view of soil classification, can be taken as fairly even. Thus almost the entire cane belt can be said to fall within one soil zone. The steeply undulating and rolling topography of the area is not conducive to the formation of a mature profile. As a result of the influence of the passive soil formers is evident in the formation of the different soil types. Thus far some ten soil types have been differentiated, and I propose to briefly describe their main characteristics :—

I. The coastal sandy belt :—
  (*a*) Light greyish sand (often resting on iron concretions).
  (*b*) Reddish brown sand of considerable depth.
  (*c*) Reddish brown sand overlying heavier-textured brownish red subsoil.

II. Greyish brown to dark greyish brown soil overlying a layer of iron gravel and rubble, on semi-pervious substratum gradually merging into the partly decomposed parent material.

III. Light greyish brown to grey sandy loam sandy loam (tending coarse) soil with a layer of rock rubble and pebbles overlying the partly decomposed parent material.

IV. Dark greyish brown sandy loam surface horizon overlying loam to heavy loam on conglomerate layer of soil with partly decomposed material resting on partly weathered parent rock.

V. Dark greyish brown loam to heavy loam overlying reddish brown to brownish red heavy loam.

VI. Greyish gravelly loam with a layer of rubble and quartz fragments in subsoil overlying the partly weathered rock (occasionally a reddish brown).

VII. Chocolate brown clay loam surface soil on reddish brown clay loam to clay.

VIII. Dark brown to black clay loam to clay on weathering parent material.

IX. Alluvial soils—actual river deposits.

X. Valley soils, partly waterlogged—of colluvial and/or alluvial origin.

I.—The Coastal Sandy Belt.

This consists of a belt of sandy soil stretching along the entire length of the Natal and Zululand coast. It is of variable width, anything up to three miles, but widens out considerably in the vicinity of Empangeni and Umfolozi, where it ranges from 15 to 20 miles in width. It cannot be connected with any geological formation and is thought to be of recent coastal deposit, probably carried some distance inland by the winds.

(*a*) *Light greyish sand (often resting on iron concretions).*

This constitutes the broad strip of land of moderately flat topography, stretching along the coast and vlei areas of Zululand to the east of Empangeni and Umfolozi. Groundwater in several places is found very close to the surface, giving rise to waterlogging, and it is thought that such anaerobic conditions, coupled with the acid reaction, are responsible for the removal of the iron compounds. The subsoil is usually lighter in colour than the surface and is of an open to loose structure. Iron concretions are found in the substratum, usually at four feet or deeper, and often form iron hardpan. The soil reaction is acid and soluble salts are entirely absent.

The water-retaining capacity and fertility of the soil are low—it requires heavy dressings of fertilizer, incurring expenses unwarranted by the yields realised, and is therefore not used for cane production. The soil, where it has been cultivated, is planted to trees, mostly eucalyptus and firs.

(*b*) *Reddish brown sand of considerable depth.*

The topography of this soil typs is undulating to rolling. It lies immediately adjacent to the grey sandy belt described under (*a*) or adjoining the coast. This belt varies considerably in width and if often found mixed with type (*c*), where it has been more recently deposited by wind.

The profile is very homogeneous, consisting of a reddish brown friable to open sand of considerable depth.

The soil reaction remains somewhat acid and the percentage of soluble salts is low. Its moisture-retaining capacity is fair, although cane is inclined to suffer from drought. Regular applications of fertilizer are essential. The Co.290 variety seems to thrive best on this soil type.

(*c*) *Reddish brown sand overlying heavier-textured brownish red subsoil.*

This is the most inland portion of the sandy coastal belt and the topography remain steeply undulating to rolling.

The surface horizon is a reddish brown friable sand identical to type (*b*) and often extends to a depth of some four feet, overlying an illuvial horizon of heavier texture. In isolated instances this horizon has been exposed on the surface by wind and surface erosion. It varies from clayey sand to heavy loam in texture and is often of a rather compact structure, with a decidedly richer red coloration than the surface. From the horizon downwards the texture again gradually becomes lighter. This more compact horizon is probably due to eluviation of clay and iron colloids from the upper horizon and their deposition in the B horizon (the concentration of iron oxides would account for the deeper red colour).

In soil reaction and salt content this type is similar to (*b*). It retains moisture very well and yields good crops under average fertilizer applications.

Both Co.290 and Co.281 do well, but the latter is understood to give better yields.

The appearance of black heavy mineral grains as irregular small patches on the surface of types (*b*) and (*c*), especially after a rainy period, when it collects in channels of flowing water, is somewhat puzzling. Mr. Beater has analysed and found it to consist chiefly of magnetic iron oxide. The following facts suggest a possible explanation for its presence.

Not infrequently Magnetite is a constituent of these basic igneous rocks, and this mineral is liberated as very fine grains when these rocks undergo physical, and even to some extent chemical, weathering.

This mineral product would find its way into the watercourses and be transported by rivers to the ocean, from where it will be deposited with the sand. Having a high specific gravity, it separates out easily from the sand in running water.

This theory is partly substantitaed by the heavy deposits of this mineral found at the mouths of rivers after floods.

II.—Greyish brown to dark greyish brown soil, overlying a layer of iron gravel and rubble, on semi-pervious substratum gradually merging into the partly decomposed parent material.

The sequence of horizons as set out above only applies to the more mature type of profile, i.e. where the topography is gently sloping to moderately level. In the less mature stage the iron oixde is present in the form of scattered concretions only, and often entirely absent. The soil horizon not infrequently rests on a rubble layer immediately overlying the weathering parent rock and even this rubble layer is sometimes poorly defined.

Owing to the rolling topography and frequent intrusions of basic igneous rocks on the summits of koppies the surface soil is considerably modified under colluvial influence.

The surface horizon normally consists of a greyish brown fine sandy loam to loam with good crumbly structure. Dark greyish brown clay loams and greyish sandy loams commonly occur, due to colluvial influence, as stated above. This overlies a somewhat cemented and compact layer of heavier texture, formed as a result of eluviation of colloidal material from the surface. Deeper ploughing should easily disintegrate this—in fact, it is felt that continual cultivation to the same depth has in many instances materially contributed to its formation. The average soil depth is from 12 to 18 inches, but in unusual instances it extends some 4 feet.

The gravel horizon immediately underlying this layer consists of round iron oxide gravel resembling buckshot (less frequently some soft iron oxide concretions), with clay and more or less rock rubble and pebbles. The rubble and pebbles consist of sandstone, quartz, quartzite, basic igneous material, and even shale fragments. Often the rubble and clay predominate in this horizon, while at times it consists almost entirely of iron oxide gravel. The presence of iron gravel and concretions is dependent upon the periodical waterlogged conditions in the substratum which are essential for their formation, and these conditions, in turn, are governed by topography and permeability of the substratum.

Contrary to an opinion previously expressed regarding the possible colluvial origin of the rock rubble in the iron oxide gravel layer, the opinion is now held that they are derived from the conglomerate pebbly constituents of the Dwyka Tillite and the Ecca Shales and Sandstones, which are more resistant to weathering.

Below the gravel layer lies a plastic and compact silty clay of a yellowish to yellowish brown colour, with blue and grey mottlings. This layer varies considerably in thickness from several feet to barely an inch. It overlies and gradually merges into the partly decomposed parent material.

The yellowish brown clay-like weathered material constitutes the impervious substratum responsible for the waterlogged conditions in the subsoil during the rainy season. Conditions seldom favour the desiccation of this layer, and where fissures have occurred, these are filled by infiltration of colloidal material from the horizons above. Roots are confined to these fissures.

The soil reaction increases with depth from acid in the surface horizon to distinctly alkaline in the substratum. Soluble salts are not present in the surface soils, but the substratum sometimes contains up to 0.25 per cent. This should not deleteriously affect crops, as these salts cannot approach the surface under climatic conditions normally prevailing.

The water-retaining capacity of this soil type is generally good, but the amount of moisture stored and available to crops is often limited by soil texture and depth and the nature of the gravel horizon.

Good cane yields are obtained with normal applications of fertilizer.

A study of the geological map reveals very close association between the Ecca and Dwyka series of the Karroo System of sedimentary rocks and the distribution for this soil type thus far established. This close correlation is explained by the fact that these formations readily give rise to the semi-pervious substratum.

At Empangeni a similar soil type was found overlying the granite.

III.—Light greyish brown to grey sandy to sandy loam (tending coarse) soil with a layer of rock rubble and pebbles overlying the partly-decomposed parent material.

The soil consists of a greyish brown sand to coarse sandy loam of good friable structure, usually some four feet in depth, but occasionally extending six feet and more. The subsoil layer, some 12 inches thick, is almost wholly composed of coarse gravel and pebbles with little soil, these coarse aggregates constituting the harder components of the rock, which are more resistant to weathering.

This rests upon a moderately thick horizon (some two feet) of sandy material, mixed with partly decomposed rock fragments which gradually merges into the weathering rock. In a few instances at Umzinto the gravel and pebble horizon was found to contain a fair amount of iron oxide concretions.

Soil reaction is decidedly acid and no soluble salts are present. The soil retains moisture favourably, but regular applications of fertilizer are essential for good yields.

This type corresponds closely with the occurrence of Table Mountain Sandstone at the lower altitudes.

IV.—Dark greyish brown sandy loam surface horizon overlying loam to heavy loam on conglomerate layer of heavy soil with partly weathered material resting on partly decomposed parent rock.

The surface horizon, approaching two feet in depth, consists of a greyish brown, often dark, sandy loam to loam with some coarse material. The structure is coherent friable or crumbly, the second foot usually being more cemented than the surface. This rests on a heavier subsoil (loam to heavy loam) of a coherent nutty to granular structure. This horizon is about 18 inches in thickness and contains some quartz gravel and Table Mountain Sandstone fragments. The colour changes to brown, often with a reddish tinge.

Underlying this is a conglomerate horizon of yellowish brown decomposing sandstone with heavy soil containing much quartz grit and gravel in pockets. Again this gradually merges into the partly weathered parent material.

Soil reaction is on the acid side and soluble salt content is negligible.

Water-retaining capacity is good and cane yields on this soil type are satisfactory under normal fertilizer practice.

This soil type occurs more inland at the higher altitudes extending from some four miles west of Maidstone. They can also be closely associated with the Table Mountain Sandstone.

V.—Dark greyish brown loam to heavy loam overlying reddish brown to brownish red heavy loam.

The surface layer consists of a dark greyish brown light loam with a coherent crumbly structure. In the next horizon the texture changes to heavy loam and the structure becomes more granular—this extends to some three feet from the surface. Below this there is a rapid change in colour to reddish brown, the red becoming more intense with depth. The texture remains unchanged, but the structure becomes very crumbly and almost friable. This extends to a considerable depth, usually exceeding six feet.

Soil reaction is acid and no soluble salts are present.

The soil has good physical properties, retains moisture well and yields good cane crops.

Only a small patch of this soil type was investigated, lying some 20 miles inland at an altitude of 2,000 feet. The profile is lateritic in character ,but this may be strongly influenced by the presence of basic igneous intrusions found in the vicinity, which lend themselves more readily to lateritic weathering.

VI.—Greyish gravelly loam with a layer of rubble and quartz fragments in subsoil overlying partly decomposed rock (occasionally red brown soil).

The soil consists of a greyish gravelly loam with the gravelly constituents often predominating. The structure varies from fairly open to somewhat cemented. The soil extends some two to four feet in depth. This rests on a layer of coarse quartz grit and gravel, with little loamy material, sometimes fairly cemented.

Underlying this horizon of coarse material is the partly decomposed parent rock. Often, however, a thin layer of heavy material, containing much grit and gravel is sandwiched between the coarse gravelly horizon and the weathering rock. This would appear to be a very immature stage of the profile described under II.

The soil is again acid in reaction and contains no soluble salts.

Although statements to the contrary are made, it is thought that the water-retaining capacity of this soil type is low, and heavy dressings of fertilizer are essential for satisfactory crop yields.

In the vicinity of Umzinto a patch of this gravelly soil has a distinctly reddish brown colour.

The gravelly soil type is closely associated with the occurrence of granite. The high percentage of quartz in this rock would make it very resistant to weathering, and hence its association with this coarse and immature soil type.

VII.—Chocolate brown clay loam on reddish brown clay loam to clay.

The surface horizon consists of a chocolate brown clay loam of coherent crumbly structure. The subsoil is of a very homogeneous heavy texture, but the colour gradually changes with depth from reddish brown to brownish red. The structure becomes coherent granular and somewhat compact at 12 inches, but improves again from 48 inches downwards, where it becomes more crumbly. Frequently fine iron oxide gravel is irregularly deposited throughout the entire profile.

The soil is of good depth, usually exceeding six feet, good physical properties, and retains moisture well.

The soil reaction is acid, and the P.O.J. varieties are doing exceedingly well on this soil type in Zululand. Organic fertilizers are not regularly applied, and it is the practice to fertilize less heavily and less frequently on this soil type. An extensive area of this soil lies to the north of Empangeni. Speaking generally, this red soil can be said to cap most hills in the coastal belt, and is frequently encountered along the slopes of hills.

The weathering is lateritic in origin and the soil type is associated with the frequent intrusions of basic igneous rocks—mostly dolerite—found throughout the Natal Province.

VIII.—Dark brown to black clay loam to clay overlying weathering parent material.

The surface soil is usually a dark brown to black clay loam of a very good crumbly structure overlying an almost black fine nutty to crumbly clay. The clay loam seldom exceeds six inches in depth, and the entire soil horizon varies from 10 to 18, or sometimes even 24 inches.

Underlying this is the yellowish brown weathering material, with some of the black clay, which apparently gravitated into fissures. This mixed horizon seldom exceeds a foot in thickness, merging into the parent material in varying stages of weathering.

The surface soil has a slightly acid reaction, with pH in the vicinity of 6.0 per cent., while it becomes more alkaline with depth, though seldom exceeding 8.0 per cent. Soluble salts are present to a negligible degree and would offer no difficulty even under irrigation.

The moisture-retaining capacity is good and roots were found to penetrate well into the decomposing rock. This type yields very good cane.

The only patch of this type actually investigated is at the Experiment Station, where it caps the hill. From observations during our travelling in the cane belt this black soil occurs in much the same way as does the deep red soil, but to a much lesser extent. In all cases noted the underlying rock has been found to be dolerite, and hence we associate this type as well as the red soil with the frequent basic igneous intrusions.

Immediately the question arises: why are some of the soils deep and red and others shallow and black, while both are derived from the same rock and presumably under similar conditions? The following facts suggest a possible explanation :—

The comparatively restricted soil depth affords opportunity for a constant supply of calcium from the parent material, which combines with humus to form black calcium humate.

It is noticed that the red soil is more prevalent on the northerly slopes, while the black clays are more confined to south-westerly slopes.

The effect of heat on the northerly slopes would be to accelerate the dehydration of iron compounds, accompanied to a lesser extent by decomposition of organic material.

The fact that the black soil is more alkaline supports the theory of the presence of a larger proportion of calcium compounds.

IX.—The alluvial soils—river deposits.

One can hardly draw a distinct line of demarcation between the soils deposited by rivers and those deposited in the valleys. Due to the rough and rugged topography of the country, such valleys, with their comparatively deep deposits of soil, are plentiful. The latter soils, however, are found more close to their seat of origin than the former, and will be discussed separately.

Very small areas of soil deposited along river banks were investigated by us, the most important being a section of the Umfolozi Flats, where extensive experimental work has been carried out.

The profiles vary considerably in texture and structure and the layers as deposited by individual floods are fairly well demarcated.

Closer to the river bank the soil is of a lighter texture than away from it, but silt usually predominates in the texture, with fine sand much in evidence near the river. High water tables are often encountered and elaborate drainage systems are called for. These difficulties are accentuated by occasional floods.

The soil is usually for a favourable structure, but heavy compact layers are not unknown.

Soil reaction varies but is on the alkaline side, while a small percentage of soluble salts is present.

The soil retains moisture very well, and its supply is constantly being augmented by the comparatively high water table. The fertility of the alluvial soil is kept high, probably due to the frequent addition of silt by floods.

Exceptionally good crops are realised with all varieties and fertilizing is seldom practised.

X.—Valley soils—partly waterlogged—of colluvial and/or alluvial origin.

Due to the steeply undulating and rolling topography a large proportion of the surface soil is made up of soils derived from wash from hillsides; this applies more especially to soils in valleys and depressions. In the absence of regular artificial drainage waterlogging often results, giving rise to poor and acid soils.

These valley deposits vary so greatly that no one general description can suffice to include all. They vary from comparatively coarse sand to compact and plastic clay, depending upon their locality and source.

Where efficient drainage has been applied the water table often acts beneficially in supplying a perpetual source of moisture for the plant.

In the heavier soils lime concretions are often found in the subsoil.

The soil reaction of the more sandy deposits is distinctly acid, but alkaline conditions often prevail in the subsoil, especially in the heavy clay type.

We noted several instances where attempts had been made to establish P.O.J. varieties on this waterlogged soil type—all without success. It appears that Co.290 is most adaptable to the waterlogged soils, especially those of a more sandy nature. This cane variety fares poorly on a heavy boggy soil and Co.281 has to be resorted to.

GENERAL REMARKS.

These very brief general descriptions of the main soil types may leave the impression that the soil survey of the cane belt would be comparatively straightforward. Let me hasten to disillusion anybody who may hold that opinion.

The very steeply undulating and rolling topography, coupled with the abundant intrusions of igneous rocks, results in rapid soil changes within comparatively short distances. Changes of soil texture, structure, depth and reaction all occur to a greater or lesser extent within a very small area, and such occurrences have to be mapped accordingly.

Such frequent soil variations demand an intensive survey, with trial pits comparatively close together. Much time and labour could be saved by making use of a soil auger, instead of the practice of having holes dug. An occasional hole will be necessary to make a closer study of the profile, especially as regards its structure.

Regarding the usual field laboratory analyses normally carried out on all samples, I am of opinion that the determination of soluble salts (i.e. electrical resistance) can profitably be omitted, unless a special problem involving saline soils has to be studied. In the cane belt more useful information can be obtained by determining the pH of the soil, at the surface as well as at various depths. With discretion, even the pH determination can in several instances be omitted, which would then obviate the necessity for taking any samples at all.

THE ADVANTAGES OF SOIL SURVEY AND MAPPING.

This brings me to the final stage of my talk—the linking of soil survey data with field and laboratory tests, in order to supply a basis for sound agricultural practice.

The moment soil survey is mentioned the following questions automatically arise :—

(i) How much will such a survey cost ? And
(ii) How are we going to benefit by it ?

Cost is influenced by a multitude of factors and circumstances (often unforeseen), and to do justice to the first question I would have to give a very detailed discussion of the subject, with which I do not propose to bore you.

I shall endeavour to briefly review the benefits accruing from a soil survey.

The ultimate object of the survey is the compilation of a set of soil type maps covering the entire sugar cane belt, and including all possible topographic and surface detail. A study of the map will reveal at a glance all details about the soil, except its fertility and productivity. These are the aspects which mainly interest the planter and in which connection the Experiment Station is approached for information.

Chemical analyses of composite representative samples, though acting as an approximate guide, do not fully meet the case, and actual field trials have to be resorted to.

Much progress has recently been made in the field of rapid chemical methods for determination of available plant foods, but reference will briefly be made to this subject later on.

When the selection of the most suitable cane variety for any particular locality or soil has to be made, there is no alternative but to have recourse to actual field trials.

In this connection the agronomist will be guided by any predilection the variety or its parents may have shown for climate or soil type in its native country. A thorough knowledge of the soil type will greatly simplify his selection of probable experimental sites for quick results.

If the soils throughout the cane belt were homogeneous the task of the agronomist would be much simplified—minor climatic variations would be his sole concern.

The heterogeneity of the soil is very striking and it is immediately evident that different forces have been at work to produce the various results, and each soil would have to be considered on its own merits from the agricultural point of view. The soil map would supply not only the soil variations, but also the extent of each recognised type.

One would expect that field trials should be so distributed over the different soil types, that each type will be represented in proportion to its extent of occurrence. The large area allocated to experimental work on alluvial soils appears to be out of proportion, while other soil types remain unrepresented.

The ideal site for experimental work would be one where inherent fertility is absolutely homogeneous. Although a soil survey alone cannot show actual fertility, it can at least determine several factors which directly influence plant growth, e.g. soil depth, texture, structure and general characteristics of the profile. If homogeneity of these factors has been shown the possibility of a fertility gradient has been reduced to a minimum.

Recent complex layout of experiments is said to reduce the effect of heterogeneity. Should a soil survey establish soil heterogeneity, with how much accuracy can the experimenter apply the results of his experiment to any one or more of the soil characteristics ?

Everybody conducting experiments in the sugar cane belt will agree that several varieties or types of soil are recognised and named from surface indications; and some actually try to confine their experimental work to such types or "fields." Why not establish the types more scientifically and accurately by carrying out a soil survey ? Surface indications are very misleading, as has been successfully proved by our survey of numbers of field trials.

One has to take it for granted that, while a soil type reveals certain characteristics regarding profile formation, it will also fall within certain limits as regards its fertility. Thus the results obtained experimentally on a fixed type of soil could, within limits, be applied generally to that soil type occurring elsewhere. If this principle be adopted, much duplication of experimental work could be avoided by mapping the soil.

In this respect reference can again be made to rapid chemical methods. Should a correlation be established between field trials and rapid chemical methods for any given soil type, I think it can safely be assumed that the application of rapid chemical methods to that soil type will be fully justified. However, on another type of soil a different, or no, correlation may be found. It is only after having properly mapped the soils that these rapid chemical methods could eventually be generally applied, perhaps still with some reserve. I think the advantages of rapid chemical methods are fully realised, but I fear their general applicability to such a heterogeneous soil belt is well-nigh impossible without some system of soil mapping.

The soil map supplies a means for comparison of results of fertilizer and other experiments in different localities within the same soil type, and differences can be correlated with climate or other factors.

The compilation of a soil map, with all soil types on each farm demarcated in detail, will greatly simplify the task of supplying advice *re* fertilizers and cane varieties which planters may require from time to time. In the meantime a reconnaissance study of any farm by a soil officer would reveal all soil types, and from available results at the Experiment Station the necessary information can be supplied.

For the correlation of results of field trials with soil mapping, I wish to quote from a paper by de Vries[4]. Referring to a detailed mapping of the sugar plantations of Netherlands Indies, he says: ". . . The results of the field experiments were then, of course, plotted in these soil type maps, and one of the slides to be shown illustrates how these results, for phosphatic manures, agree with the soil types. At the same time the soil map shows in which places further field experiments should be undertaken."

I understand that every effort has been made in the past to lay out the co-operative field trials of the Experiment Station on as representative soil types as possible. However, in this the co-operation of the planter is necessary, and it is not always possible to find someone in the desired locality who can be "bothered" with such extra trouble. After such co-operation has been procured a site has to be decided upon to suit the planter—this is not always the most suitable from the experimental point of view. Experiments laid out from surface indications have often proved most disappointing, due to soil variations.

While the planter's difficulty is fully appreciated, in that he often has to suffer great inconvenience through having an experiment laid out in the centre of a large field, often only recently planted, I cannot help but stress the necessity for the closest co-operation between the planter and the Experiment Station.

Once a soil map has been compiled, the Experiment Station will be in a better position to lay out a comprehensive programme of work and field trials and the necessary co-operation could then, perhaps, be more readily procured.

Where irrigation is contemplated, an accurate and thorough knowledge of the soil to a considerable depth is not merely a valuable adjunct, but an absolute necessity. This fact has been proved over and over by experiences overseas as well as in our own country. "The place of soil science in agriculture" formed the subject of the presidential address of Sir E. J. Russell at the Third International Congress of Soil Science, held at Oxford in 1935[5]. He emphasizes the necessity for mapping the soil in every detail before irrigation is embarked upon, and adds: "When one remembers the enormous cost of a large irrigation scheme the dangers of starting it without the survey are obvious."

It is my firm conviction that an equally detailed study of the soil profile is indispensable for the correct interpretation and application of results of field trials. By applying the principles as set out by de Vries, it will probably be possible to establish close correlation between plant food constituents and certain specific soil characteristics. Such correlation may suggest a more simplified system of soil mapping than has at present been found necessary.

Should it be considered inadvisable at this stage to continue with the mapping of the soils of the sugar belt, on the grounds of finances especially, a thorough investigation of all experimental sites should not be neglected. The information so obtained and compiled will form a sound foundation on which the agronomist can base the advice he is required to supply to the planter. By means of rapid reconnaissance surveys soil types could be identified and the requisite advice tendered, provided the officer is conversant with the soil characteristics of each field trial.

Before concluding my plea on behalf of soil survey I wish to re-quote (this was already quoted by J. V. Cutler at your 1936 Conference) the words of de Vries[4] in connection with crop production in the Netherlands Indies, including a goodly proportion under sugar cane:—

> "Of the four chief expedients discussed, plant analyses, for various reasons, played only a minor role in the Netherlands Indies. Soil analysis, favoured at first, lost importance and was replaced by large scale field experimental work, and this, for some crops, more or less exhausts the possibilities. *Modern soil type mapping combined with soil analysis on modern lines, is proving a better base for the layout of field experiments and the interpretation of their results.*"

Yet more emphatic and striking is the following paragraph taken from the presidential address of Sir E. J. Russell[5]:—

> "One of the striking services that soil science has rendered in recent years has been in surveying the soils of the different countries and in the preparation of maps on which any desired part of the information can be represented. This is now recognised as an essential preliminary to all agricultural

developments, reclamations and irrigation schemes, and it forms an integral part of any organised development of agriculture such as is now being carried out in many of the countries of the world. To start an important agricultural development without a preliminary soil survey is to run serious risk of disaster."

I can assure you of the co-operation of the Division of Chemical Services if you should care to approach us on any matter concerning our sphere of work, provided we are in a position to do so.

In thanking you for your courtesy, attention and patience in listening to a subject probably not new to most of you, I can only hope that I have met with some degree of success in illustrating the advantages of completing a soil map (in detail) of the Natal and Zululand sugar cane belt.

References.

[1] Joffe, J. S.: "Pedology," 1936.

[2] Robinson, G. W.: "Soils, their Origin, Constitution and Classification," 2nd edition, 1936.

[3] "Soil, Vegetation and Climate," Tech. Comm. No. 29 Imp. Bur. of Soil Sc., 1934.

[4] de Vries, O.: "Soil Fertility Studies in the Netherlands Indies," Trans. of the 3rd Inter. Congr. of Soil Sc., Oxford vol. 2, 1935.

[5] Russell, Sir E. J.: "The Place of Soil Science in Agriculture," Presidential Address, Trans. of the 3rd Inter. Congr. of Soil Sc., Oxford, vol. 2, 1935.

* * *

The PRESIDENT: Extended his thanks to the Division of Chemical Services for allowing Mr. Rosenstrauch to read this paper.

Mr. DODDS: Said he had long felt the necessity of the soil survey work. He recalled the fact that with the aid of the Division of Chemical Services the Experiment Station had been thoroughly surveyed recently. This same work had now been extended to the co-operative field experiments, and should prove of great value. He concluded by congratulating the writer on his helpful report.

Mr. LINTNER: Thought the soil was a medium which was too often overlooked. Mr. Rosenstrauch had reminded us that the soil was a living thing. He would like to see more co-operative work carried out between soil analysts, botanists and agronomists—in fact a close association of all scientific workers, which would then help to solve our soil problems.

Mr. DU TOIT: Asked in how far the Russian system of soil classification could be applied to our South African soils. Secondly, what did other countries such as South America, Australia and perhaps India, all with similar climatic and geological conditions to ours, do about soil classification.

Mr. ROSENSTRAUCH: Replying said that the Russian system had been evolved through the severe climatic conditions prevailing there. He said Mr. van der Merwe, in charge of soil surveys, had actually found that the soils of South Africa could be climatically classified, but with certain reservations. He went on to say that there were intra-zonal types formed by purely local conditions. The soils of the Sugar Belt could be grouped climatically in two zones only. In these soils there also exists a close correlation between our soil types and the original geological formation.

The American system of soil survey was based more or less on local conditions. giving the soils of each province a purely local name. They would thus refer to a Natal loam, a Natal red sand, a Transvaal black turf, or a Western Province mountain soil. Other countries may base their classification on vegetation. A special committee had been appointed at the International Congress of Soil Science to go into and compile data about the systems used by the various countries for soil mapping and classification.

The PRESIDENT: With the reading of this paper comes the last of our Congress, and, incidentally, the last minute of my stay in the Presidential chair. During the last four days I think we have covered a lot of very interesting ground. This has been a very successful Congress indeed. Many questions have been studied, and the interest has never flagged.

I want to thank all the members who have contributed papers. I want to thank Dr. Hedley for his self-sacrifice in making a success of this Annual Congress, and I cannot forget to associate also our stenographer, who is silent, but still does a lot of work.

Now, gentlemen, before leaving the Presidential chair, you will pardon me in my swan song if I sound a personal note. Last year, when I was elected to this Chair, some very kind words were said to me. I think Mr. Moberly said he was pleased to see that I was put here as a representative of a class of men who, by their efforts, their energy, and their pioneer work have started this Industry. I was doubly appreciative of those words. I can only say that I am still more pleased to see that the work of our Association is going to be continued by a gentleman of the ability and energy of Mr. Murray. I am very sorry that he is not here. Mr. Murray, to my mind, represents the type of Scotchmen who have continued and perfected the work which we, as pioneers, have done for this Industry. But, after all, it matters little whether your past President was borne in the Isle of France, or whether the new one comes from the banks of the Clyde, when you have worked for a quarter of a century in this land you have become a true South African. I speak as a South African. I can tell you when I went to France a few years ago, it was the proudest day of my life when I stood up in a Conference and represented South Africa.

I can only say this, in finishing, that I picture the work of our Association as an image which will appeal to those of the Roman and Greek culture, which has been revived lately in our sports. You have heard of the race when the torch is carried from hand to hand. It does not matter who carries the torch. The torch goes on. It is the same with us. The torch we are carrying in our work is the torch of light, the torch of efficiency, and I am sure that in passing my torch to Mr. Murray, I am handing it to very efficient hands.

Mr. DODDS: Mr. President. Before we disperse, I would like to express the admiration and gratitude that I am sure we all feel to you for having occupied the chair in such an excellent way over the past four days. I felt last year that we could not have made a better choice. That anticipation has been fully justified by the events, not only of this Congress, but of the past year. My only regret is that we have not secured your services for another term of office.

(Applause).

Congress concluded.