# PLANT NUTRIENT DERIVATION FROM SOIL MINERALS

## By R. R. MAUD

### Factors Influencing Soil Formation

#### (a) Parent Material

The mineralogy of a rock is largely determined by which of the three great divisions of rocks it belongs to. Thus igneous and metamorphic rocks are in general composed of crystalline minerals, whereas sedimentary rocks are often composed of fragments of minerals, or even other rocks.

Igneous rocks are subdivided into three main groups:

(i) Coarsely crystalline rocks which solidified at depth, termed "plutonic" rocks. A common example s granite.

(ii) Somewhat finer-grained rocks which solidified at moderate depths as dykes or sheets in fissures in pre-existing rocks. These are termed hypabyssal or ntrusive rocks. A common example is dolerite.

(iii) Fine-grained and glassy rocks which solidified at the earth's surface. These are termed volcanic, extrusive or effusive rocks. An example is basalt.

It must be here pointed out that of late there has arisen a school of thought which does not regard all granites as having been molten during formation, but rather that some granites may have been formed *in situ* from pre-existing rocks by a process of ionic transfer termed "granitisation."

Sedimentary rocks can be subdivided into two main groups:

(i) Those deposited by wind and water, thus having a "mechanical" origin.

(ii) Those deposited by precipitation of chemical compounds in aqueous solution, thus having a "chemical" origin. In the first group will be found the final insoluble products of rock mineral decomposition such as the clay minerals, along with those rock minerals which have resisted weathering processes and remained unchanged, such as quartz, iron and titanium oxides, and such minerals as zircon and tourmaline. The second group is subdivided according to the nature of the chemical compound deposited, in this group being found such rocks as limestones and phosphorites.

Metamorphic rock mineralogy depends on the nature of the original rock and the type of metamorphism to which it has been subjected, characteristic minerals being formed in each case. Metamorphism involves heat or pressure or both, the resulting minerals being stable under the conditions prevailing at the time of formation, but if these conditions are altered, as when these return to normal, the newly-formed minerals are generally no longer stable and are very susceptible to alteration, as by the agencies of weathering. Thus not many metamorphic minerals are stable under atmospheric conditions, the only relatively durable metamorphic minerals being kyanite, stauralite and epidote.

On the Natal coast, parent rock is the dominant factor determining the formation of soils as other soil-forming influences have not had time to mask or obliterate the initial features imparted to the resultant soil by its underlying parent material.

#### (b) Climate

It has been stated by Mohr and Van Baren (1954) that present-day overhead climate is a much over-estimated factor in soil formation, while the significance of the soil climate has been neglected or at least underrated. Natal coastal soils with one exception are "young," climate not having had time to modify the dominant effect of parent material.

#### Topography

The Natal coastal belt is at present undergoing active dissection by rejuvenated river systems, consequently most of the topography is hilly or rugged, the soils thus being immature in profile development. Where flat areas have resisted the inroads of later erosion cycles, older soils do occur.

#### Vegetation

Vegetation has not influenced soil formation very much on the Natal coast, except perhaps in the case of low-lying swampy areas and in the climatic soil exception previously mentioned. R. Loxton (Univ. of Ghana, private communication) has expressed the opinion that the present savannah vegetation on the so-called T.M.S. mist belt soils (which are the exception), cannot be reconciled with the high acidity (pH $\pm$ 4.6), the high organic matter content, low silica, and high iron and alumina of these soils which occur generally above 1,000 feet on the inland T.M.S. plateaux. He suggests that a temperate forest would be necessary to affect the soil to that extent, as the ordinary T.M.S. soils are not nearly so acid and have but little organic matter. Thus this soil may be largely a legacy of a former vegetation differing from that now prevailing.
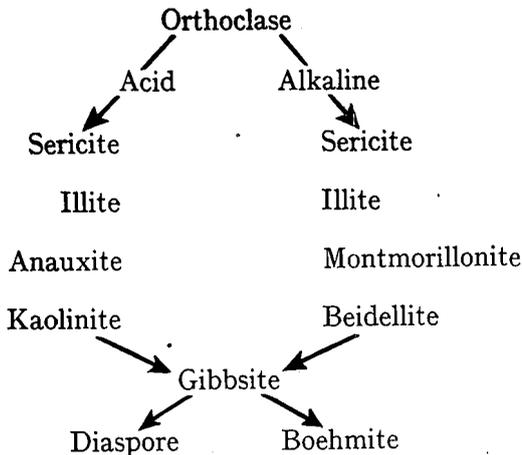
### Chemical Weathering of Minerals in Soils

When a mixture of different minerals in one rock is subjected to chemical weathering some minerals are more susceptible to these agencies and weather

faster than others. Weathering sequences have been worked out for minerals of high specific gravity, coarse grained, colloidal minerals, and also combinations of these categories.

In general minerals can be grouped into four classes according to their stabilities:

Extremely unstable: Olivine, hornblende, augite.

Slightly stable: Garnet, epidote, calc-alkali plagioclases.

Stable: Potassium feldspar, muscovite.

Very stable: Zircon, rutile, ilmenite, magnetite, quartz.

The same mineral, when subjected to weathering under differing conditions may give rise to diverse secondary minerals. Thus

morphous substitutions may have occurred. The minerals are platelike in structure and show a marked basal cleavage. The oxygen tetrahedron which consists of four oxygen atoms close packed about a silicon atom is one of the basic structural units of clay minerals. Tetrahedra of this kind may share oxygens and form sheets having the composition $(Si_2O_5)_n$. These sheets may be bonded through common oxygen atoms, with sheets of aluminium or magnesium octahedra.

Kaolinite is the major clay mineral found in soils along the Natal coast, and consists of silica and alumina sheets in a 1 : 1 ratio. Two other clay minerals which are also fairly common in this region are montmorillonite and illite, comprising silica and alumina sheets bonded in a 2 : 1 ratio.

Orthoclase
/    \
Acid     Alkaline
↓      ↓
Sericite     Sericite

Illite      Illite

Anauxite    Montmorillonite

Kaolinite    Beidellite
\    /
Gibbsite
/    \
Diaspore   Boehmite



KAOLINITE: Sheets held by hydrogen bonds. Space between sheets is fixed and is inaccessible for surface reactions.
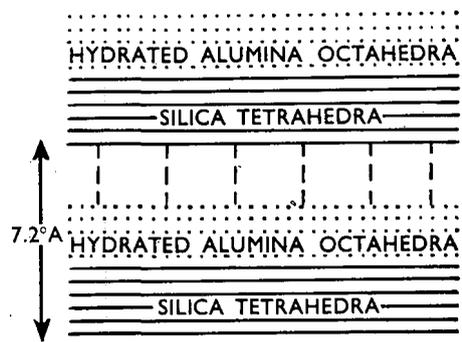
in this manner a totally different suite of soil minerals may be formed from the same primary mineral.

In clay size mineral particles the stability sequence is somewhat different from those of coarser-grained minerals, because surface area becomes great enough to hasten weathering of minerals which are otherwise more stable in coarser sizes. Clay-size particles are mainly those less than $2\,\mu$ in diameter, but the sequence also applies to some extent to the 2–5 $\mu$ size range (fine silt). The order of stability of clay-size minerals has been given by Jackson et al (1948, 1952), with the most stable stage last as gypsum, calcite, olivine, biotite, allite, quartz, muscovite, interstatified 2 : 1 layer silicates and vermiculite, montmorillonite, kaolinite, gibbsite, haematite and lastly the titanium oxides and zircon.
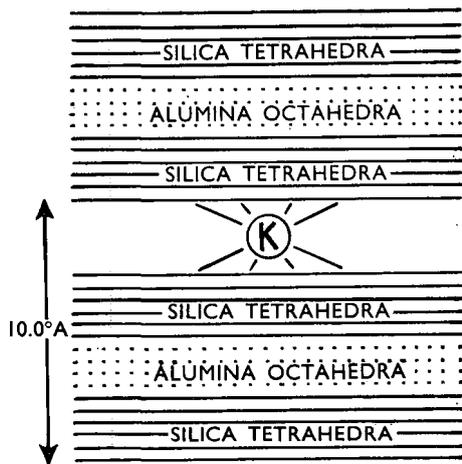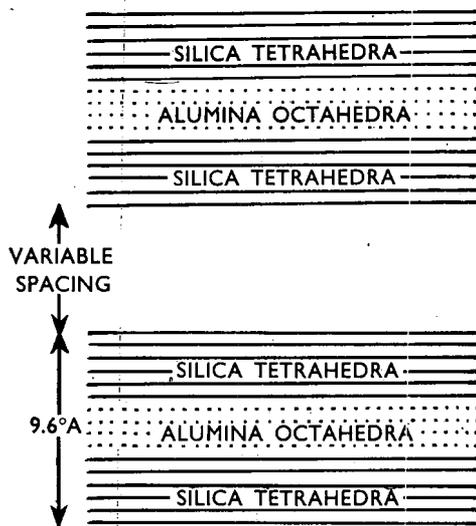
A word is here necessary as to the structure of clay minerals, as this largely determines how the clay minerals behave in the soil. The clay minerals are secondary hydrated alumino-silicates, in which iso-



ILLITE: Sheets held by potassium bridges. Space between sheets is partly accessible for surface reactions.

SILICA TETRAHEDRA

ALUMINA OCTAHEDRA

SILICA TETRAHEDRA

VARIABLE SPACING

SILICA TETRAHEDRA

9.6°A ALUMINA OCTAHEDRA

SILICA TETRAHEDRA

Montmorillonite: Intersheet spacing varies with amount of water present. Entire surface between sheets is accessible for surface reactions.

(After Russell)

Ionic substitution of $Al^{+++}$ for $Si^{++++}$ and $Mg^{++}$ or $Fe^{++}$ for $Al^{+++}$ are found in the 2 : 1 type clay minerals. This gives the clay mineral crystal a negative charge. Some negative charge also comes from unsatisfied bonds at the edges of clay crystals and from dissociation of $H^{+}$ from surface-exposed hydroxyl groups.

The charge on the clay mineral enables it to react with other charged particles and ions. The attraction between the negatively charged clay and such positive ions as $H^{+}$, $Ca^{++}$, $Mg^{++}$ and $K^{+}$ constitutes an important property of the soil. The attracted ions are held in a state of dynamic equilibrium with similar ions in soil solution and can be "exchanged" from soil particles when changes of concentration in the soil solution occur.

Jackson and Sherman (1953) have related the stages of chemical weathering to index minerals that characterise each stage. The thirteen stages are grouped under early, intermediate, and advanced processes of weathering. Soils in the early stages of weathering are subdivided into the saline, calcareous and ferromagnesian and feldspar stages of weathering, the more weathered stage being last. In the intermediate stage are found the quartz, mica-illite, interstratified 2 : 1 layer silicates, vermiculite and montmorillonite stages of weathering. With more advanced weathering the montmorillonite stage passes into the kaolin stage which is in turn followed by the gibbsite-allophane, haematite-goethite and anatase-leucoxene stages. This last stage is the approximate limit to which the weathering of a soil is able to proceed.

## The Derivation of Plant Nutrients from Soil Minerals

The minerals composing the soil play an important part as a direct source of plant nutrients. By weathering of soil minerals, the elements required by plants for nutritional purposes are released and made more available to the plants. The nutrient ions to be considered in connection with release by weathering from soil minerals include:

(a) potassium, calcium and magnesium, among the common cations;

(b) phosphorus, nitrogen and sulphur and the common anions; and

(c) iron, manganese, copper, zinc, boron and molybdenum among the trace elements.

### (a) (i) Potassium

As far as is known potassium is absorbed by plants as the $K^{+}$ ion, either from solution, or by the mechanism of contact exchange (Tisdale and Nelson, 1956). Potassium occurs in the soil in one or more of the following forms: (a) as a constituent of primary minerals such as feldspars and micas; (b) associated with clay minerals as exchangeable potassium; (c) within a clay mineral lattice as non-exchangeable potassium; and (d) as water-soluble potassium salts (Wiklander, 1954).

The primary potassium-bearing minerals that occur in soils are orthoclase feldspar, microcline (having the same chemical composition as orthoclase but differing in crystallographic properties), muscovite, a fairly stable mica, and biotite, a less stable mica. Sericite or secondary muscovite is a compact or fibrous potassium-bearing mica, derived by alteration from potash feldspars.

Most secondary clay minerals contain some potassium, but only illite contains a substantial amount, namely 4 to 5 per cent K (Wiklander, 1954). The clay minerals have the power to fix the potassium cation from the soluble salts in run-off and drainage waters. The availability to plants of potassium from primary minerals is slight, but is of the order biotite > muscovite > potash feldspars. Biotite in addition is also an important source of natural magnesium.

The only readily available form of potassium in the soil is that held as soluble potassium. Its amount depends on many varying factors, including the amount of exchangeable potassium with which it is in equilibrium and from which it is difficult to distinguish. The soluble potassium is usually present in low concentrations and is thus not of much importance. Plants have therefore to rely on exchangeable potassium for their requirements and on the reserve of more difficultly available potassium. Exchangeable potassium is adsorbed on soil materials such as clays and is readily replaceable with neutral salts in a short time. It is lower in sandy than in

clayey soils owing to less weathering, stronger leaching conditions and lower exchange capacity. Drying favours the adsorption of potassium at the expense of calcium and magnesium. Exchangeable potassium is completely available to plants either directly by contact exchange or indirectly by its being in equilibrium with soluble potassium.

Fixed potassium is so firmly bound in soil minerals that it is not replaceable with neutral salts. It is considered to be bound between the basal planes of the micaceous minerals in the hexagonal oxygen cavities normally occupied by $K^+$ as a lattice constituent. On weathering, part of the lattice potassium ions migrate out of their position between the unit layers, being replaced by such ions as $H_3O^+$, $Ca^{++}$ and $Mg^{++}$. Potassium ions can again replace these ions and contract the expanded lattice, thus becoming fixed. Fixed potassium is only available to plants at the rate at which it is released by defixation. Soil materials that fix potassium are chiefly illite, but also the montmorillonite group on drying, vermiculite against replacement with the ammonium ion, and to a lesser degree the primary minerals biotite and muscovite. Kaolinitic minerals, feldspars and organic matter do not have this property (Wiklander, 1954).

Lattice potassium is regarded as the chief form of non-exchangeable potassium occurring in the potassium-bearing primary and clay minerals. The capacity of a soil to release potassium by weathering depends on the potassium minerals and on the soil texture or specific surface. The higher the specific surface of a soil, the greater its ability to release potassium by weathering. In the clay fraction of soils, the content of primary minerals decreases rapidly with decreasing particle size, biotite, feldspars and muscovite disappearing in that order.

In the soils of the Natal coastal belt the potash content varies considerably on account of the variation in the potash-minerals in the parent rocks. In general the granitic basement rocks such as the Tugela schist, amphibolite and the granite itself contain fair amounts of potash minerals such as microcline and orthoclase, the derived soil thus containing moderate amounts of this element. The soils derived from the sedimentary rocks such as the Table Mountain sandstone and middle Ecca sandstone are by contrast rather low in potash as the parent rocks are composed almost wholly of quartz. The recent sands also fall within this category. The Dwyka tillite and Lower Ecca shale soils have fair amounts of potash, its retention being favoured by the clayey texture of these soils.

## (a) (ii) Calcium

Calcium, like potassium, is absorbed by the plant as the $Ca^{++}$ ion, either from soil solution or by the contact exchange process. The calcium present in

soils had its origin in the rocks and minerals from which the soil was formed. Soils derived from limestones and dolomites, as would be expected, are high in calcium, whereas soils derived from non-calcareous sandstones and shales in a humid climate have only small amounts of calcium. Much of the calcium of sedimentary rocks was removed while they were undergoing sub-aqueous deposition, while further losses were sustained during soil formation. Soils derived from igneous rocks, especially basic igneous rocks, contain appreciable amounts of both clacium and magnesium.

Calcium is released from such minerals as dolomite, calcite, apatite, calcium feldspars, amphiboles, pyroxenes and from secondary clay minerals. The fate of released calcium is much less complex than that of potassium. Calcium ions on release can be either (a) lost by solution in drainage waters; (b) absorbed by organisms; (c) adsorbed on clay particles; or (d) be reprecipitated as a secondary calcium compound. As far as is known there is no fixed form of calcium comparable with that of potassium. Calcium in acid humid region soils occurs largely in the exchangeable form and as undecomposed calcium minerals.

The factors which influence calcium availability to plants are the amount of exchangeable calcium present, the degree of saturation of the exchange complex, the type of soil colloid and the nature of the complementary adsorbed ions. The type of clay influences the degree of calcium availability, the 2 : 1 type clays requiring a much higher degree of saturation for a given level of plant utilisation than the 1 : 1 type clays. Montmorillonite clays require a calcium saturation of 70 per cent or more before there is sufficient release for growing plants. Kaolinitic clays are able to satisfy calcium requirements at a saturation of only 40 to 50 per cent (Tisdale and Nelson, 1956).

Apart from the soils derived from dolerite, amphibolite and Tugela schist the majority of the soils of the Natal coastal region are relatively low in lime content. The arenaceous sandstone soils with their porous texture permit ready removal by leaching waters of any lime present, though there is some retention of lime in the more clayey soils. The lime in the dolerite and amphibolite is contained in the plagioclose feldspars which are usually lime rich, and on weathering this is released.

## (a) (iii) Magnesium

Magnesium, like calcium, is absorbed by the plant as the $Mg^{++}$ ion, either by absorption from soil solution or by the contact exchange process. Soil magnesium is derived from the decomposition of rocks containing such minerals as biotite, dolomite, chlorite, serpentine, olivine and others. On decom-

position of the mineral, the liberated magnesium may follow much the same processes as calcium as regards adsorption by clays, etc. Available soil magnesium is in the exchangeable and/or water-soluble form. The formation of unavailable forms of magnesium in soils is favoured by the presence of 2 : 1 type clay minerals, the magnesium ion probably being entrapped between the expanding and contracting sheets of the mineral. The coarse-textured soils of humid regions are generally low in magnesium. In general, magnesium in the soil follows the behaviour of calcium and potassium under similar conditions.

Magnesium content in Natal coastal soils follows very closely that of calcium, being found in the greatest amounts in the ferromagnesian-rich rocks such as dolerite, amphibolite and Tugela schist. It is derived in the main from biotite, hornblende, pyroxenes and olivine which are associated with these rocks.

### (a) (iv) Sodium

The sodium content of soils is of the order of that of potassium, being derived mainly from the decomposition of sodic plagioclase feldspars. Sodium occurs in the exchangeable form in soils, but as it is the most loosely-held of the metallic ions, it is readily lost to leaching waters. Sodium affects the dispersion of both clay and organic matter and its presence in fine-textured soils has an adverse effect on their structure.

Sodium being derived mainly from the plagioclase feldspars is usually associated with soils derived from rocks rich in this material. Thus the dolerite, amphibolite and Tugela schist and to some extent the granite have moderate amounts of sodium, the soil texture influencing the degree of retention. The Dwyka tillite soil contains fair amounts of sodium, derived mainly from igneous erratics in the parent rocks, and this gives it its objectionable 'setting' properties.

### (b) (i) Phosphorus

The native phosphorus in soils, discounting that in organic matter, which may make up to three-quarters of the total, occurs mainly in the form of the mineral apatite. This may occur as finely-divided fluor-, chlor-, or hydroxy-apatite. The rate at which apatite dissolves is very slow, the only way of speeding this up being by the addition of organic matter, which on decomposition yields carbonic and nitric acids. Much of this acid is, however, spent on other soil minerals, only a small part being available for the liberation of phosphorus.

Phosphates are retained or fixed in acid soils either by precipitation of insoluble compounds from solution, reaction with hydrated sesquioxides, or by reaction with silicate clay minerals. Phosphorus reacts with iron and aluminium to form complex insoluble orthophosphates, while in the presence of colloidal iron and other sesquioxides the phosphorus is adsorbed on the surface to form a basic iron or aluminium phosphate. It has been postulated that phosphate ions may combine directly with clays of the 2 : 1 (montmorillonite) and 1 : 1 (kaolinitic) types, by either replacing a hydroxyl group from an aluminium atom or by forming a clay-calcium-phosphate linkage (Tisdale and Nelson, 1956). Clays with a low $SiO_2 : R_2O_3$ ratio will fix larger amounts of phosphate than those with a high ratio, probably due to the exposure of a greater number of hydroxyl groups in the 1 : 1 type than the 2 : 1 type clay.

Calcium - saturated clays will adsorb greater amounts of phosphate ions than sodium clays. In alkaline conditions there is high calcium activity, this with the high pH favouring the formation of insoluble tricalcium phosphates, which may revert eventually to hydroxy-apatite in part. Phosphate ions may also be precipitated on the surfaces of solid calcium carbonate particles, while calcium-saturated clays also fix phosphate ions. Under alkaline conditions most of these conditions probably play a part in phosphate fixation.

Organic matter, from which humus is derived, increases the solubility of phosphorus, possibly by either forming assimilable phosphohumic complexes, or by anion replacement of the phosphate by the humate ion, or by coating sesquioxides with humus, thereby preventing phosphate adsorption.

Almost without exception all the soils occurring on the Natal coast are deficient in phosphorus, the parent rocks containing but little apatite. Soils derived from dolerite are very low in phosphates whereas the T.M.S. mist belt soils have fair quantities of it, on account of the abundance of iron oxides present, although little is in the available form, the balance being in combination with the iron oxides. The sandy soils in general have lower amounts of phosphorus than do the more clayey soils such as the Lower Ecca and Dwyka.

### (b) (ii) Nitrogen

The primary source of soil nitrogen is the air from which it is removed by atmospheric electrical discharges, by several species of micro-organisms living in or on the soil, by plant tissues, or by solution in fresh and salt waters. Fixed nitrogen occurs in igneous rocks in small amounts (about 25 ppm. in granite and basalt). This is slowly leached on weathering probably as ammonium chloride from basic rocks, but in a different form from acidic rocks, as fixed nitrogen is still liberated by weathering granitic rocks long after any soluble nitrogen would have been leached away (Ingols and Navarre, 1952). The ammonium ion occurs in micas and vermiculites liberating nitrogen compounds on prolonged weather-

ing, and also possessing the power of undergoing fixation in slowly-available mineral forms.

### (b) (iii) Sulphur

Sulphur occurs in rocks mainly as metallic sulphides, which on weathering by oxidation, produce sulphuric acid and resulting sulphates in the soil. The most common of these is gypsum ($CaSO_4.2H_2O$), on account of its relative insolubility compared with other sulphates. Another insoluble sulphate is barite ($BaSO_4$), but this is very uncommon. Shales tend to be higher in sulphur than other rocks, often containing much pyrite, while basic igneous rocks also contain more sulphides than acidic rocks. The derived soils, therefore, contain more sulphates than chlorides and nitrates which are lost from the soil more readily.

Not much is known as to the occurrence of this element in the coastal soils. Some of the parent rocks, however, do contain appreciable amounts of sulphides such as pyrites, notable in this regard being the Lower Ecca shale and to a lesser extent in some dolerites. The rocks associated with the granite may also, in some instances, have some amounts of sulphides. Soils derived from these rocks then may be expected to contain an adequacy of this element.

### (c) (i) Copper

Copper and cobalt are usually associated with the more basic rock types and are relatively rare in the more acid quartzitic and feldspthatic igneous and sedimentary rocks. Copper deficiency generally occurs in either coarse-textured acid soils low in native copper, and subjected to leaching, or in excessively-limed coarse or fine-textured soils, or in organic soils. Graham (1953) found that trace element deficiencies occurred in the more advanced stages of weathering as indicated by the analysis of quartz, feldspar and heavy minerals in the soil. Gibbsite was noted as related to a copper deficiency, the mineral not being found in any non-deficient soils. Thus some soil minerals may influence the availability of heavy metals to plants.

Copper deficiency in sugarcane has been noted on the Natal coast by J. L. du Toit (1956). It occurred on a very sandy porous soil derived from pre-Granite quartzite which resembles very closely the T.M.S. Apart from this, not much is known about copper occurrence in this region though soils derived from igneous and metamorphic rocks should have larger amounts of copper than soils derived from sedimentary rocks.

### (c) (ii) Iron

Iron occurs in soils as the minerals haematite, ilmenite, magnetite, geothite and in many hydrated colloidal oxide forms such as coatings and in isomorphously substituted positions in micas and 2 : 1 layer silicates. The iron in soil originated mainly from the decomposition of ferromagnesian minerals, pyrites and other primary minerals which on weathering are oxidised and converted to various oxides. The availability of iron to plants is dependent on its reduction to the more soluble ferrous form. Most soils contain relatively large amounts of total iron, but the amount of soluble or exchangeable iron is in most cases low.

There is an abundance of iron in all the Natal coastal soils but in many cases it may not be in the available form. Iron deficiency (chlorosis) has been noted on various soil types which are known to contain appreciable amounts of this element, (Recent Red Sand).

### (c) (iii) Manganese

Manganese occurs in the soil as hydrous oxides such as pyrolusite, manganite and braunite, all having a low solubility and being derived mainly from primary ferromagnesian minerals. Manganese is thought to exist in three valence states in the soil, (a) divalent $Mn^{++}$, present as an adsorbed cation or in soil solution its presence favoured by acid conditions (b) trivalent manganese, existing as the reactive oxide $Mn_2O_3$, favoured by neutral conditions; and (c) the tetravalent manganese $Mn^{++++}$ existing as the very inert oxide $MnO_2$, its presence favoured by alkaline conditions. In extremely acid soils, manganese may exert a toxic influence on plants, but in many cases the manganese is precipitated by soil phosphates before low pH's are reached.

Manganese deficiencies may be found in soils derived from sedimentary rocks while igneous rock soils usually have sufficient amounts of this element. The Recent Red Sand contains considerable quantities of manganese, the amount of manganese present in most soils being related to their iron content. As most of the Natal coastal soils have relatively large amounts of iron, the amount of manganese present is usually sufficient for plant nutrition.

### (c) (iv) Zinc

Zinc is thought to occur in soils mainly as an isomorphously substituted cation in an octahedrally co-ordinated position, normally occupied by magnesium in minerals with the aluminium octahedral arrangement (Elgabaly, 1950). Zinc content is low on coarse sandy soils, but in organic soils it may be present in toxic amounts. It is thought to occur in small amounts in soil solution and the exchangeable form, but in greater amounts in an insoluble form.

### (c) (v) Molybdenum

Molybdenum deficiencies are characterised by occurring on highly-weathered soils (Graham, 1950),

having high amounts of quartz and very low quantities of feldspars. In contrast to other micro-nutrients it is released by alkaline conditions. Molybdenum is essential for plants to receive nitrogen in forms other than the ammonium ion, and is also necessary for fixation of atmospheric nitrogen by legume bacteria.

### (c) (vi) Boron

Almost all boron in soils is derived from the resistant mineral tourmaline and other boro-silicates, which on weathering slowly release boron. Tourmaline may also contain some fluorine. Most of the available boron is held in organic matter and is released by microbial decomposition. Coarse well drained sandy soils are usually low in boron content, those having a fine-textured subsoil not being quite so deficient.

Tourmaline is a common constituent of granites on the Natal coast so a deficiency of this element would not be expected in this or related soils. Not much is, however, known of the boron content of soils derived from sedimentary rocks, though there would appear to be a sufficiency of this element in most soils.

### (c) (vii) Silicon, Aluminium and Chlorine

Silicon constitutes a considerable part of the ash of some plants, especially grasses. It may substitute partially for phosphorus in plants and as most plants grow in a medium that has a silicon equivalent of between 65 to 95 per cent silica as $SiO_2$, it is easily understandable why plants do contain some amounts of this element. As silicon occurs in most rocks, ranking second only to oxygen in occurrence in the lithosphere, and aided by the fact that silica is very durable and withstands weathering, it is not surprising that soil as the product of rock decay is very largely composed of silicon dioxide.

Aluminium is not essential to plant growth but is accumulated in plants growing on acid soils. It is a major constituent of some clays and is derived mainly from the numerous alumino-silicate minerals that abound in rocks.

Chlorine has recently been proved to be a plant nutrient, neither fluorine nor iodine being able to substitute for it, though bromine may assist materially after the manner that sodium may sparingly substitute for potassium in plant nutrition. Chlorine, unlike other nutrient elements contained in rocks, is not fixed by soil colloids. It in fact exhibits the phenomenon of negative adsorption. Unlike most other micronutrients also, chlorine compounds formed in the soil are highly soluble. Some natural chlorine does occur in rocks, especially volcanic ones, but the amount is not very great, the main source of continuing supply being rainwater.

A more detailed mineralogy of the soils of the Natal coastal belt has been undertaken by the author and will appear shortly in the forthcoming volume on the *Soils of the South Coast of Natal* by Dr. B. E. Beater. This subject therefore has been only very summarily dealt with in this publication, as space also would not permit greater detail.

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**Mr. du Toit** (in the chair) said that this paper would be of great value when published in our proceedings for it would form a useful reference in any future examination of our soils.

**Dr. Brett** asked if any forests were in existence that were capable of producing the high organic matter and other characteristics of the mist-belt soils, and how long the soil would retain its characteristics after the destruction of such forests.

**Mr. Maud** replied that no such forests are now known in these areas. They were now mostly grassland or open forest land. He did not know of course what had happened in the past, say thousands of years ago. He was hoping that a study of fossil pollen population might give a guide as to the age of the soil type in the mist-belt area. Not being a botanist he was unable to say how long effects of vegetation would remain impressed on the soil, but radical changes might be long-enduring after vegetal destruction.

**Mr. Rault** said that Natal Estates had had the carbonatation process in use for about forty years, and during the course of that time not far from a million tons of calcium carbonate had been applied under the form of filter cake to the soil This must have had some reaction on the soil by now. As far as chlorine was concerned Natal Estates molasses was very high in this element. He wondered if this was due to the plant selecting chlorine from the soil or was it merely the effect of the proximity to the sea.

**Mr. Maud** replied that he thought it must be due to the proximity of the sea. It would be interesting to know what the chlorine content of cane growing inland was, compared with cane grown near to the sea. As far as the excessive use of lime was concerned some soils in the vicinity of Mount Edgecombe appeared to consist almost entirely of calcium carbonate, but in general the high lime content of these soils was responsible for the presence of iron deficiency chloritic symptoms.

**Dr. Douwes Dekker** said that last year he published the analyses of many samples of molasses which should have some connection with the composition of the soil from which the cane was derived.

**Mr. du Toit** said that it was most important to know the minerals which were derived from different rock formations. As far as the quantity of phosphorus and potash in soils was concerned, however, that depended largely upon the fertilizer practice of the past. In the case of trace minerals these were largely derived from the parent rock and as such, were a very different proposition.