VII. MINERALOGY OF THE SAND FRACTIONS

The gravel fractions (over 2mm) and coarse sand fractions (2 – 02 mm) were examined under the binocular microscope, and in the mountain and stony rise soils, an approximate estimate of the composition of the coarse sand was made by counting the number of grains of each mineral species present in a sample of 200. The percentage of each mineral by volume in the fine sand (0.2 – 0.02 mm) was determined as described in a previous paper (Nicholls, 1936).

Numerous examples of each soil type were examined, an no significant mineralogical difference in the composition of the fine sand was found between individual samples belonging to the same type, except in type 1 (see Table XIX)., where the high variability is only to be expected. Results are therefore given in Table XX as an average for the whole type. The samples were taken from varying depths in the soil profile, in some cases a complete profile being examined to a depth of 5 feet. The figures quoted in Table XX, however, are compounded using only one mean figure for each profile; the average for types 4 to 8, for example, is the average of five figures, these being the means of profiles 014, 170 – 1, 180 – 1, 270 – 1 and 280. The amount of sand in the soil changes with depth, but the mineral composition of this and is remarkably constant (See Table XXI). One important variation is shown by the number of sponge spicules present, which is high in surface soils and falls rapidly with increasing depth, but since these spicules are organic remains and not soil minerals, they have been omitted in the calculation of results. Samples from different depths of the same profile have then been incorporated in the calculation of the average.

Table XIX. – Mineral Composition of Fine Sand of Various Samples of Type 1

Number of Grains of Principal Minerals in Sample of 500

No	400a	4001a	4011a	402a	403a	405a	406a	408a	409a
Quartz	275	1094	169	228	260	190	261	174	292
Plagioclase	73	87	132	93	97	103	71	93	59
Iron Oxide	50	138	102	71	74	57	61	82	64
Augite	4	26	41	76	39	30	39	68	20
Olivine	9	18	23	18	4	20	15	23	10
Rock	23	35	29	11	21	25	20	29	20

Table XX. – Average Percentage Volume of Important Minerals in Fine Sands

Soil type	1. Stony Rise Loam		3. Thistle Zone		4 – 8 Slope and Swamp Soils		9. Mountain Soils	
Quartz	50.3	(4.4)	86.8	(0.6)	93.7*	(0.1)	76.6	(2.2)
Plagioclase	**19.38***	(1.8)	**8.7**	(1.7)	3.9	(0.2)	**10.0**	(0.7)
Iron Oxide	**8.4***	(1.5)	1.7	(0.6)	1.2	(0.1)	3.3	(1.0)
Augite	**12.3***	(1.5)	**1.01**	(0.1)	Trace		**0.4**	(0.15)
Olivine	**2.2***	(0.4)	0.8	(0.3)	0.5	(0.05)	**1.5**	(0.4)
Basalt	**7.6***	(1.1)	**0.3**	(0.15)	Trace		-	
Basalt glass	-		-		-		**7.7***	(1.7)

NOTE Figures in black type are significantly higher than those for mature soils (Types 4 – 8)
Percentages significantly the highest for each mineral are marked with asterisk.
Figure in parenthesis are the standard error of the means.

Table XXI. – Mineral Composition of Fine Sand of Typical Crabhole Profile (270)

Number of Grains in Sample of 500

Horizon No. Depth							
Quartz	390	449	458	462	458	453	392
Plagioclase	58						49
Iron Oxide	24	23	20	18	19	30	40
Augite	1	-	2	3	4	-	1
Olivine	8	9	6	5	4	8	6
Rock	-	-	-	-	1	-	-
Zircon	5	5	5	5	5	4	3
Tourmaline	5	3	3	5	4	4	4
Leucoxene	1	6	5	1	2	-	5
Epidote	-	-	-	-	1	-	-
Sponge spicules	8	2	1	1	2	1	-

JThe standard error of the mean of the results fro each type has been calculated in the usual way, on the assumption that each is a random sample of a uniform population.

Great difficulty was found in distinguishing with certainty between the quartz and the labradorite present in these soils. /the refractive indices of the two are almost identical, and the felspar often appears quite clear, untwinned and with no trace of cleavage. Methods of staining were tried for the separation of these minerals, but hydrofluoric acid was necessary to attack the felspar, and no concentration could be found at which all doubtful cases arose, therefore, the axial figure was determined in order to identify the mineral. It was found quicker to determine the quartz-felspar ratio by a separate count of 100 grains, in which the axial figures were determined when necessary.

A. Description of Minerals

Type 1 (Stony Rise Brown Loam)

The gravel of these soils consists of greatly decomposed basalt fragments, with a few grains of quartz and buckshot.

Coarse Sand –

- Quartz (61 per cent) – Generally sub-angular, sometimes rounded. Iron-stained along cracks and in hollows. Inclusions common; iron oxide, rutile needles, apatite, zircon, tourmaline and fluid inclusions have been noted, the last often arranged in bands in the manner characteristic of reef quartz.
- Basalt (39 per cent) – Fragments of crystalline basalt, highly decomposed.
- Augite (trace) – Irregular broken fragments, with "titanium violet" tinge. Appear to be quite undecomposed.
- Buckshot (trace) – Rounded and polished ironstone pellets.

Fine Sand –

- Quartz – As in coarse sand.
- Plagioclase – Irregular fragments, quite undecomposed. Refractive index about 1.565, indicating labradorite.
- Augite – As in coarse sand.
- Iron Oxide – Magnetite or ilmenite. Irregular grains and fine needles, usually fresh..
- Basalt – As in coarse sand.
- Olivine – Irregular fragments, characteristic olivine green with deep red-brown iddingsite border. Quite fresh.
- Zircon – Rounded grains or crystals with rounded terminations.
- Tourmaline – Rounded grains and short, stumpy prisms with rounded edges. Blue and brown.
- Hyalite – Water clear, irregular fragments.
- Broken fragments of the spicules of *Spongilla* are also present.

Type 2 (Stony Rise Clay)

The gravel and coarse sand of these soils contain only quartz and buckshot. The fine sand minerals are similar to those of Type 1, but the rock fragments, augite, and plagioclase grains are much smaller and show more alteration. Small rounded grains of leucoxene are also present.

Type 3 (Thistle Zone Soils)

Usually, the gravel and coarse sand of these soils contain only quartz and buckshot, but small fragments of decomposed basalt occur occasionally. The fine sand contains the same minerals as Type 1, but the augite and plagioclase show signs of alteration. Rutile, epidote, andalusite, and leucoxene have been observed in soils of this type.

Types 4 – 7 (Low Slope and Swamp Soils)

The gravel and coarse sand fractions of these soils consist of quartz grains with a varying amount of buckshot. Electromagnetic separation shows that an average of 2 per cent of the coarse sand of the low slope soils is buckshot, but the percentage in different samples varies considerably and in some cases reaches 7. The fine sand contains the same minerals as Type 1, with the exception that augite occurs only in samples taken in close proximity to basalt, as when a basalt boulder (or "floater") was encountered during sampling (e.g., Table XXI, Horizons c, d, e), or when the horizon sampled rested on basalt bedrock. In such cases, the plagioclase grains are fairly large and fresh, but normally the plagioclase of these soil types consists of extremely small and somewhat rounded grains, much decomposed and sometimes almost completely converted to secondary material. Rutile, epidote, andalusite and sillimanite occur occasionally in these soils, and small rounded grains of leucoxene are also present.

Type 9 (Mountain Soils)

The gravel of these soils contains greatly decomposed fragments of scoria, and of vesicular basaltic glass, with a few rounded quartz grains. In the locality mentioned, large pebbles of quartz and sedimentary rock occur. Grains of buckshot also occur, but are very rare.

The coarse sand contains quartz (63 per cent), scoria and basaltic glass (34 per cent), olivine (3 percent), and a trace of augite and buckshot. Augite was observed only from samples taken near types of basalt, or on the central basalt plug. The olivine occurs mainly as perfectly formed crystals up to 5 mm diameter. These have a transparent red-brown appearance, but broken edges show the characteristic olivine green with a red-brown iddingsite border.

The minerals of the fine sand are like those of Type 1, except that instead of fragments of crystalline basalt, splinters of basaltic glass occur. These are irregular in shape, the conchoidal fracture giving exceedingly sharp edges. The glass is light yellow to deep brown in colour, often containing bubbles, usually quite isotropic but with some fragments showing signs of devitrification. A few specimens shoe needles of iron oxide and felspar already crystallised. The plagioclase of these soils is usually in the form of irregular fragments, but flat rhomb-shaped crystals occur which show very little cleavage, and in which the twinning is visible only when the crystal is turned on edge. The refractive index of these crystals is the same as that of the irregular grains.

B. Origin of the Minerals

The most striking feature of the minerals in the sand fractions is the abundance of non-basaltic material, chiefly quartz. This quartz, which is characterised by inclusions such as rutile and zircon, and which appears rounded and water-worn, could not have crystallised from the basaltic magma, and the grains of zircon, tourmaline, andalusite, &c., which are associated with the source of this material is the volcanic ash, since, as has been stated, the explosive rocks of Mt Gellibrand contain considerable percentages of included quartz and other non-basaltic minerals, and the proportion of these foreign minerals was probably higher in the fine material which fell over the plains. The importance of this explosive material is indicated by a comparison of the sand percentages of soils from the Mt Gellibrand area with those of basalt soils from other parts of the western plains (such as Woorndoo, below), taken several miles from the nearest volcanic cone. For example:-

	Coarse Sand %	Fine Sand %
014a (Mooleric Station)	23	40
Basalt soil from Woorndoo	2	22

The large fragments of olivine which occur in Types 4 to 7 probably came from the ash, since the explosive rocks of the mount show high percentages of large olivine crystals, and the occurrence of olivine in the soils of the plains is not connected with proximity to a stony rise.

It has been suggested elsewhere (Nicholls, 1936) that foreign material is commonly added to soils by the wind, and this is undoubtedly the case with much of the fine sand in the Mt. Gellibrand area. The non-basaltic minerals derived from ash and aeolian material would expect to be similar, since they must be stable detrital minerals. Sponge spicules, however, have not been observed in the tuff, and therefore indicate the influence of wind transport. The coarser material is unlikely to have been transported long distances by the wind, and the sand percentages quoted above show that the addition of aeolian material cannot be responsible for all the non-basaltic minerals in the Mt Gellibrand soils.

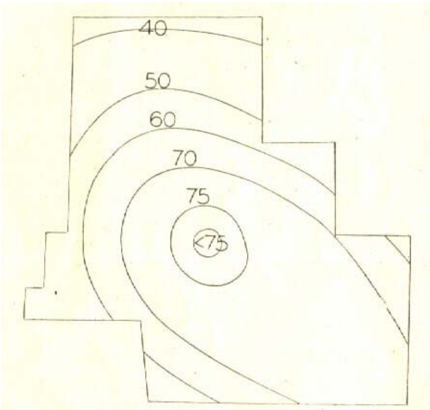

Fig 7 – Lines of equal percentages of total sand in top six inches

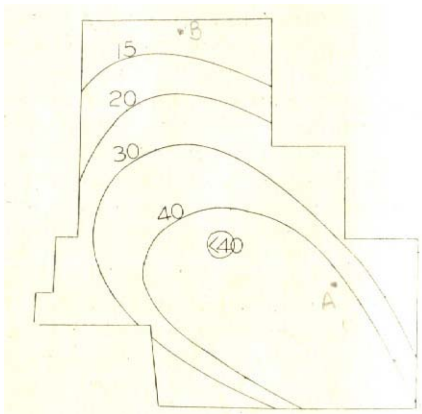

Fig 8 – Lines of equal percentages of coarse sand in top six inches

The relation of the sand percentages of the soil to the volcano is shown by Figures 7 and 8, which give respectively the total sand and coarse sand of the top six inches of soils from the low slope type. The lines of equal sand content from elliptical bands surrounding the mount, and the shape of the bands, like the shape of the contours of the mountain, shows that the prevailing winds during the period of eruption were from the north and north-west. The very sandy nature of the extreme south-east of the area is striking. The figures for coarse sand show greater regularity than those for total sand, possibly because of the inclusion in the latter wind-blown material the distribution of which is not related to the mountain. The mineral composition of these sands is similar, but the percentage of total sand in the soil varies from 32 in the north to 75 in the south and south-east, while the corresponding variation in the coarse sand is from 7 to 41.

It seems clear that the basalt was covered by showers of ash, possibly in the form of mud, and that the lower-lying parts received additional ash washed off the stony rises. One might expect to find a point in the profile where the percentage of quartz sand suddenly fell on passing from the weathered ash to the weathered basalt. In general, however, no such sharp line has been found, so that it is impossible to estimate with certainty the depth of the original ash layer. The typical "crabhole" profile, 270, however, provides a possible example of such a definite change; the sand percentages at a depth of 10 feet (coarse sand 1per cent., fine sand 10 per cent) are of the same order as are found elsewhere in deep subsoils developed over basalt without any complications from volcanic ash. The occurrence of non-basaltic minerals in such subsoils has been mentioned in a previous paper (Nicholls, 1936), and it is suggested that this is due to the washing of sand down the cracks formed during the dry season.

Some profiles show remarkable changes in the sandiness with depth. For example, the percentage of coarse sand in profile 161 passes from a maximum of 26 at the surface to a minimum of 14 at 2 feet, and rises again to a second maximum of 23 at 3 feet, below which it falls again. Since at any point in the area the falls of ash must have varied in composition, and must have been accompanied by changes in the direction and force of the wind, one would expect some irregularity in the sandiness of the various horizons; this may well be the cause of the second maximum just quoted.

Apart from this banding, there is usually a marked decreases in percentage of sand, on passing from surface to sub-surface – invariably so in the lighter soils. There are various causes for this. The process of leaching under somewhat acidic conditions involves some washing down of clay. At the sane time, the accumulation of wind-blown sand enriches the surface in the finer sandy material. An important process on the slopes consists of the loss of the finer fractions with the run-off water, a process called "exluviation" by Marbut. A good example of this exluviation may be seen in the development of the crabhole complex in the south-west of the surveyed area (See Section VI).

The basaltic minerals are prominent only in soils which are immature owing to the influence of topography, as would be expected since all the basaltic minerals with the exception of iron oxide belong to unstable mineral species. The mountain soils show crystals of olivine and splinters of basaltic glass, but augite and felspar are not prominent, as the lava in the explosive rocks seldom to crystallised sufficiently to give large crystals of these. The brown loams on the steeper stony rises show high percentages of augite, labradorite and olivine, and grains and needles of iron oxide. These minerals are often large and irregular, and appear unweathered. On the broader type of stony rise, the decomposition of the basaltic minerals has proceeded much further.

The thistle zone soils show a small percentage of augite and comparatively fresh labradorite, apparently due to washing of these grains down fro the stony rise. These minerals are usually small grains, and shoe definite signs of decomposition. Further down the slopes the influence of the rocks of the rise is not apparent, and the minerals appear to have been derived from the tuff and the underlying basalt sheets. Apart from the high content of quartz, and occasional large olivine grains, derived from the ash, the minerals resemble those of the mature basaltic soils from the extensive plains further west. Basalt is indicated only by small and much decomposed grains of plagioclase, and by the small grains of stable iron oxide.

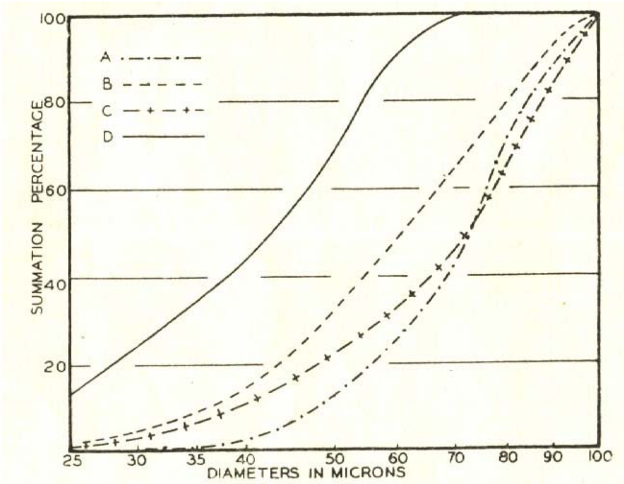

Fig. 9 – Summation Curves, illustrating percentage composition by weight of fractions of various sizes in fine sand samples.

(a) Quartz in Tuff;
(b) Quartz in sample 412a, directly above Tuff;
(c) Quartz in several mature soils on the plains;
(d) Iron Oxide in mature soils on plains

The size distributions of certain minerals in the fine sands have been plotted in Figure 9. Since the error in counting the few grains between 0.1 and 0.2 mm in a sample of 500 is unduly large, the curves cover only the distribution between 0.1 and 0.025 mm. The original figures were the number of grains of 20, 25, 30…100 microns in a sample of mixture of samples of at least 200 grains. These figures were twice smoothed by the process of adding successive pairs, and the resulting figure for each grain size was multiplied by the cube of its diameter so as to give the proportion of each size by weight. The final figures were than plotted logarithmically as summation curves. Three of the curves represent the distribution of quartz (*a*) in the tuff, (*b*) in the soil formed directly over this tuff on the mountain, and (*c*) from a mean of several mature soils on the plain. These curves illustrate the absence of the finest material from the quartz in the tuff, and the presence of this material in the soils is evidence that it has been added by the wind.

The fourth curve (*d*) shows that iron oxide occurs only below 0.08 mm diameter, as would be expected since the crystals in the basalt and the tuff are all small. The curve suggests that the iron oxide may show a maximum in the silt fraction.

Correlation between Minerals and Fertility

The soils on the rises and on the mountain (types 1, 2, and 9) are much more fertile than the soils of the low slopes and swamps. This is seen by the quality of the flora, and by the much greater quantity of organic matter in the former types. While the amount of phosphorous extractable with hydrochloric acid is also usually much higher in the former types, the correlation of fertility with the minerals of the fine sand is very striking. The soils on the rises and on the mountain are immature, and contain large amounts of easily decomposable primary minerals in their sand fractions, namely labradorite and augite in the former case, and labradorite and basaltic glass in the latter. The soils on the slopes and swamps are relatively mature and devoid of useful minerals in their sand fractions.

The surface of the minerals in the fine sand is much smaller than the surface exposed in the silt, and the mineral composition of the silt is therefore more important for plant fertility. The presence of a mineral in the fine sand fraction may, however, be taken as evidence that tit exists also n the silt fraction.

Among types 3-8, differences in fertility are due either to physical causes- such as differences in drainage or in texture- or to differences in the degree of saturation with bases; the better lime status of the thistle zone soils and the crabhole puffs is important in raising their fertility. The soils of the thistle zones, however, also have a better supply of basaltic minerals which are continually replenished by the washing of very fine particles from the rocks of the rises.