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The Trace Element of Some Soils and Rock
from Macquarie Island, South Pacific Ocean

by

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THE TRACE-ELEMENT CONTENT OF SOME SOILS AND ROCK FROM MACQUARIE ISLAND, SOUTH PACIFIC OCEAN

By D. J. Swaine⁽¹⁾

INTRODUCTION

The soils of Macquarie Island, the southernmost of the subantarctic islands of New Zealand, are predominantly peaty, although some are derived from morainic material. Descriptions and results of chemical analyses of Macquarie Island soils have been reported by Piper (1938), Mawson (1943) and Taylor (1955). This paper gives the trace-element contents of four samples of peaty material, two of morainic material and one of rock.

LOCATIONS AND DETAILS OF SAMPLES

Samples A-F were supplied by Mr. J. Bunt⁽²⁾ (numbers in brackets refer to his collection) and the following details have been derived from his information. Sample G was obtained from Mr. B. W. Taylor⁽²⁾. The approximate locations are shown in Fig. 1.

A. (No. 2) Morainic material from the Wind Desert, altitude 800-850 ft., slope 3%, aspect east. The ground is normally saturated with water, although the drainage may be free. There was very little vegetation. The sample was greyish and consisted mostly of pea-size lumps with some fine material.

B. (No. 6) Weathered material from the Wind Desert, altitude 750 ft., slope 16-20%, aspect west-north-west. Drainage was moderately free. The sample was similar to A, but was brownish.

C. (No. 8) Upland Fen Peat, altitude 750 ft., slope 10%, aspect north-east. *Pleurophyllum hookeri* was the main vegetation and the surface was well drained when the sample was taken, but it is usually water-logged.

D. (No. 18) Tussock Peat of the Coast, at sea level near shingle beach, aspect north. Very impeded drainage. Main vegetation was a tussock grass (*Poa foliosa*).

E. (No. 40) Tussock Peat of the Slopes, altitude 150 ft., slope about 70%, aspect south-west. Sample taken on lower slopes of coastal escarp-

(1) The Macaulay Institute for Soil Research, Aberdeen, Scotland.

(2) Australian National Antarctic Research Expeditions, 1950-1952.

ment leading to plateau. Impeded drainage. Main vegetation is *Poa foliosa*.

E¹. Some small rock fragments which were removed from sample E and analysed separately.

F. (No. 44) Low Moor Turf from uplifted coastal terrace, elevation 20-30 ft., very slight slope, aspect north. Very impeded drainage. The vegetation was *Agrostis magellanica*, *Ranunculus biternatus*, *Montia fontana*, some *Stilbocarpa polaris* and some *Pleurophyllum hookeri*. The whole peat layer is about 15 ft. thick.

G. Pieces of rock from the top of the ridge running from North Mountain to Handspike Point, altitude 825 ft. (same area as profile No. 7 in Taylor's collection).

Samples A-F were from the 0-15 cm. horizon. The peats (C-F) were fibrous and brown to dark brown.

METHODS OF ANALYSIS

Samples A, B and G were ground in a mechanical agate mortar and the peat samples (C-F) were dried at 80°C. before being ashed at 450-500°C. in platinum. At all stages care was taken to avoid contamination. The samples were analysed spectrographically by the cathode layer arc method (Mitchell, 1948). A mixture of equal weights of the finely ground rock or ash and carbon powder was filled into a carbon electrode which was used as cathode in a 9 ampere d.c. arc. Two one-minute exposures were taken on each of two plates, covering the ranges 2470-3550A and 3180-8000A, a Hilger Large Quartz Spectrograph (E492) being used. The spectrograms were compared visually against standard spectrograms. When the basic composition of the samples is similar to that of the standards, the precision is of the order of $\pm 30\%$.

Mineralogical analyses of A and B, and chemical analysis of G were carried out by the usual methods.

RESULTS OF ANALYSES

Ash Content and pH. The ash contents are stated relative to the weight at 80°C. The pH values were determined by Mr. J. Bunt.

| Sample | % ash | pH |
|--------|-------|-----|
| A | 97 | 6.9 |
| B | 92 | 5.4 |
| C | 61 | 5.4 |
| D | 18 | 4.6 |
| E | 22 | 6.6 |
| F | 15 | 6.6 |

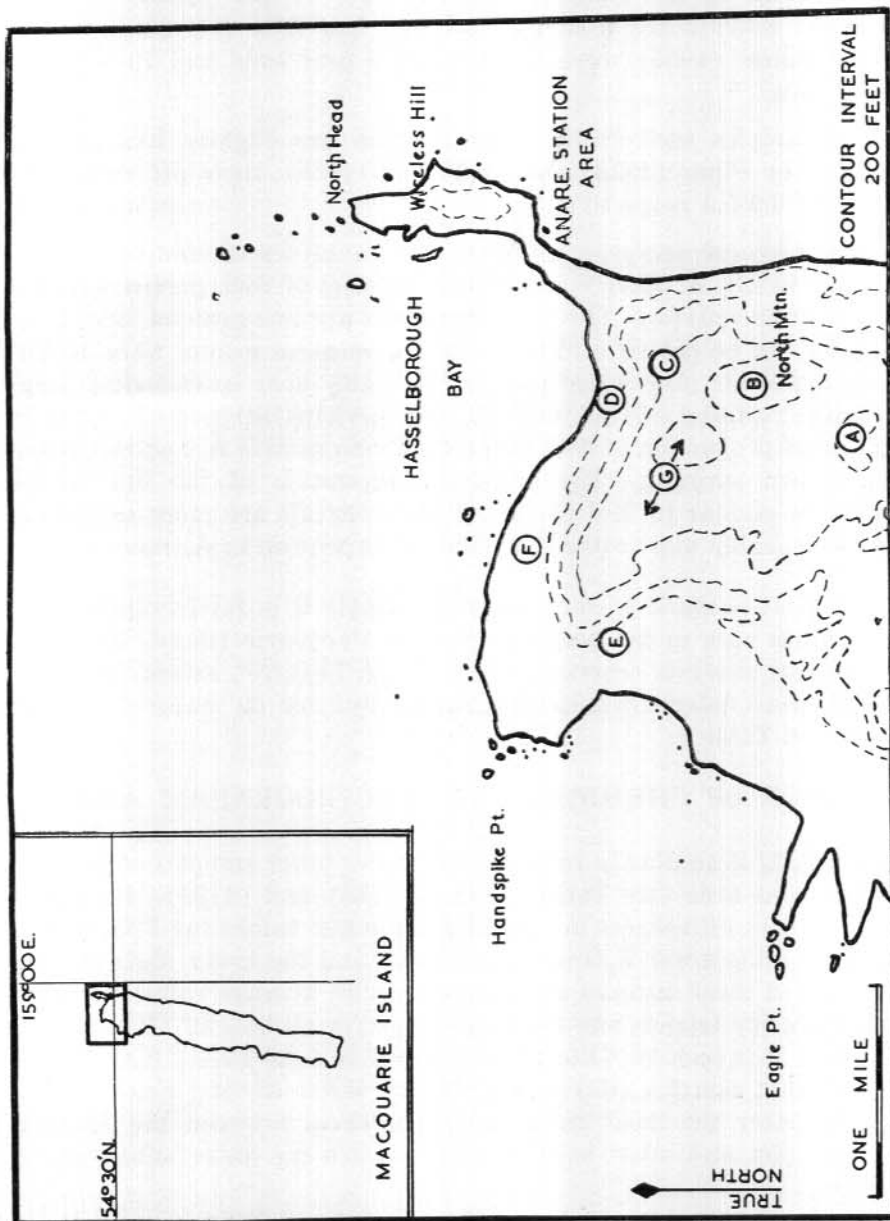


Fig. 1.—Location of Soil Samples A-G, Macquarie Island.

The ashed material from the peat samples contained some small particles of rock. This was especially noticed in sample C, which has a high % ash. It is probable that this is wind-borne material (sample C is on the windward side of the morainic wind desert). Piper (1938) found ash contents of 62-78% for 5 surface samples and 90% for a subsoil, while Taylor's values (1955) were 10-11% for 3 peat soils and 75-94% for 5 mineral soils.

The samples used in this investigation are slightly less acid than those used by Piper (1938) and by Taylor (1955), their pH values being 4.4-5.2 and 3.9-5.3 respectively.

Mineralogical analyses. Mineralogical analyses of samples A and B were done by Dr. R. Hart⁽¹⁾. Sample A consists of rock particles admixed with some fine material. The rock fragments are fine-grained, break easily and appear to be doleritic. The following mineral grains were found in the fine material: plagioclase feldspar (probably near labradorite), augite, iron oxides, altered olivine, chlorite and perhaps serpentine. Sample B has a higher proportion of rock fragments than sample A, and the material shows brown staining. The mineral composition of the fine material seems to be similar to that of A, but the minerals are more decomposed. There is probably more altered olivine or serpentine in A than in B.

Chemical analysis of rock sample. Sample G is fairly representative of the parent rock in the northern part of Macquarie Island. The results of a chemical analysis (carried out by Mr. J. Logan⁽¹⁾, except for Mn and Sr which were determined spectrographically) for its major constituents are given in Table 1.

DISCUSSION OF CHEMICAL AND SPECTROGRAPHIC ANALYSES

Sample G is similar in composition to two other samples of basic rock from the same area (see Table 1, samples (66) and (179)). Perhaps the only significant differences are the slightly lower values for P_2O_5 and TiO_2 in sample G, the lower K_2O in sample (66) and the lower MgO in sample (179). When these samples are compared with average values for basalts from the Pacific Islands and Daly's average for all basalts (P.B. and A.B. in Table 1) it is seen that sample G is lower in total Fe_2O_3 , K_2O , TiO_2 and P_2O_5 , and that samples (66) and (179) are lower in total Fe_2O_3 , K_2O and P_2O_5 . Probably the most significant differences between the Macquarie Island samples and other basaltic material are the lower values for K_2O and P_2O_5 .

The trace-element contents of the mineral soil B are similar to those of the rock G, except for higher values for Li and Cu. However, the mineral soil A has more Cr, Mo, Ni and Co and less Li, Sc, Y, Sr and Ba than sample B. The higher Ni and Co values are probably explained by

⁽¹⁾ The Macaulay Institute for Soil Research.

TABLE I
Major-Element Contents.

(values in per cent.)

| | Sample G | (66) | (179) | P.B. | A.B. |
|--------------------------------|----------|-------|-------|-------|------|
| SiO ₂ | 49.21 | 50.51 | 49.38 | 46.57 | 49.9 |
| Al ₂ O ₃ | 16.24 | 17.62 | 18.23 | 14.93 | 16.0 |
| Fe ₂ O ₃ | 7.65 } | 1.86 | 1.44 | 3.68 | 5.4 |
| FeO | — } | 5.91 | 4.94 | 8.07 | 6.5 |
| MgO | 8.03 | 7.12 | 5.45 | 7.84 | 6.3 |
| CaO | 12.22 | 11.97 | 13.75 | 10.76 | 9.1 |
| Na ₂ O | 2.84 | 2.95 | 2.97 | 2.67 | 3.2 |
| K ₂ O | 0.30 | 0.08 | 0.26 | 1.02 | 1.5 |
| H ₂ O+ | 1.87 | 0.48 | 1.60 | 0.95 | — |
| H ₂ O— | 0.47 | 0.19 | 0.64 | — | — |
| CO ₂ | — | 0.15 | — | — | — |
| TiO ₂ | 0.78 | 0.95 | 1.39 | 2.96 | 1.4 |
| P ₂ O ₅ | 0.07 | 0.14 | 0.21 | 0.34 | 0.4 |
| MnO | 0.20 | 0.08 | 0.12 | 0.17 | 0.3 |
| S | — | 0.08 | — | — | — |
| SrO | 0.06 | 0.05 | — | — | — |

— means not determined.

(66) Gabbro from the highland near the north-west corner of Macquarie Island (analysed by W. B. Dallwitz — quoted by Mawson, 1943, p. 108).

(179) Aphyric dolerite occurring as a dyke near North Mountain, Macquarie Island (analysed by A. R. Alderman — quoted by Mawson, 1943, p. 120).

P.B. Average of 116 analyses of basalts from the Pacific Islands (Green & Poldervaart, 1955).

A.B. Average of all basalts (Daly, 1933).

Spectrographic analyses. The results of the spectrographic analyses are given in Table 2.

TABLE II
Trace-Element Contents.

(as parts per million)

| | r | A | B | C | D | E | F | G | H. | K. |
|------------------|------|------|------|------|-----|-----|-----|------|-------|------|
| Ga ³⁺ | 0.62 | 7 | 10 | 10 | 4 | 2 | 1 | 20 | 23 | 25 |
| Cr ³⁺ | 0.64 | 2000 | 300 | 200 | 40 | 70 | 30 | 700 | 500 | 350 |
| Ti ⁴⁺ | 0.64 | 2500 | 6000 | 5000 | 200 | 150 | 70 | 5000 | 19000 | 5300 |
| V ³⁺ | 0.65 | 100 | 200 | 120 | 18 | 13 | 15 | 250 | 230 | 300 |
| Mo ⁴⁺ | 0.68 | 2 | <1 | 2 | 2 | 2 | 1 | <1 | <1 | — |
| Li ¹⁺ | 0.78 | 1 | 25 | 4 | <1 | <1 | <1 | 3 | 2 | 6 |
| Ni ²⁺ | 0.78 | 2000 | 150 | 120 | 18 | 13 | 23 | 200 | 80 | 70 |
| Co ²⁺ | 0.82 | 100 | 40 | 25 | 5 | 3 | 4 | 40 | 35 | 30 |
| Cu ²⁺ | 0.83 | 50 | 100 | 120 | 35 | 40 | 30 | 15 | 150 | 120 |
| Sc ³⁺ | 0.83 | <10 | 25 | 10 | 4 | 3 | <3 | 30 | 10 | 20 |
| Zr ⁴⁺ | 0.87 | 50 | 80 | 60 | 18 | <10 | <10 | 60 | 100 | 80 |
| Mn ²⁺ | 0.91 | 2000 | 2000 | 1800 | 550 | 450 | 90 | 2000 | 1000 | 1100 |
| Y ³⁺ | 1.06 | <10 | 25 | 15 | 5 | 3 | <2 | 25 | 23 | — |
| Ag ¹⁺ | 1.13 | <1 | <1 | <1 | 0.5 | 0.5 | 0.5 | <1 | — | — |
| Sr ²⁺ | 1.27 | 30 | 300 | 400 | 200 | 150 | 100 | 500 | 800 | 350 |
| Pb ²⁺ | 1.32 | <10 | <10 | <10 | 2 | 2 | 2 | <10 | — | — |
| Ba ²⁺ | 1.43 | 10 | 50 | 30 | 10 | 3 | 2 | 30 | 100 | 200 |
| Rb ¹⁺ | 1.49 | <1 | 1? | <1 | 3 | <1 | <1 | <1 | <20 | 20 |

H. Mean of 2 basalts from Hawaii (Wager & Mitchell, 1953, p. 218).

K. Mean of 2 Karroo (South Africa) dolerites (analysed by R. L. Mitchell — quoted by Walker & Poldervaart, 1949, p. 644 — Zr value from Wager & Mitchell, 1951).

Results for A, B, G refer to air-dried and for C-F to material dried at 80°C.
r = ionic radius in Angstrom units (Goldschmidt, 1954).

The following elements were not present in an amount greater than the minimum sensitivity (in brackets — referring to ash):—As (3000), Be (5), Bi (30), Cd (200), Ge (10), Hg (1000), In (10), La (10), Sb (300), Sn (5), Tl (10), Zn (300).

Lines were not found for Au, Ir, Pt.

the presence of more alteration products of olivine (serpentine?) in A than in B. This explanation is supported by the detection of Mo, as it has been shown by Wager & Mitchell (1951) that Mo occurs in olivine. The greater amount of Cr in A than in B is probably the result of an increase in the pyroxene (augite) content. In keeping with their basic character these three samples (A, B, G) are low in Zr, Pb, Ba and Rb. The low values for Pb, Ba and Rb in sample G are not surprising in view of the low value for K (Table 1), since these elements have similar ionic radii to and normally replace K.

In order to ascertain whether there are any differences in trace-element contents between the rock G and similar basic rocks from other parts of the world, the mean values for 2 Hawaiian basalts and for 2 South African dolerites have been calculated and entered in Table 2. In general there is remarkably good agreement, but the Macquarie Island rock is much lower in Cu. It should be noted, however, that the mineral soils A and B have similar values for Cu to the Hawaiian and South African samples. The Macquarie Island and the South African samples have similar, but much lower, Ti contents than the Hawaiian samples. The Macquarie Island rock is slightly higher in Ni and lower in Ba than the others, which is probably the result of higher content of altered olivine and rather lower K content.

The peaty soils (C-F) can be considered together, with the exception of C which is very similar to the mineral soil B, probably because of contamination by rock particles (it has an ash of 61% compared with 15-22% for D-F). It seems that Mo and Cu have been concentrated appreciably and Mn, Ag and Sr slightly in samples D-F. Some justification for the conclusions just drawn can be found by considering the amounts of trace elements in the ash from E and in some rocky material (E¹) separated from it (Table 3). In this case the contribution from the rocky material has probably been small since it contains 10-20 times as much Ba, Li and Rb as the ash. It is interesting to note the relatively low Ba and the relatively high Sr in the ash.

The trace elements in the actual peat material have probably been derived from the residues of decaying plants and from waters, both surface and underground. It is known that organic matter binds certain elements, e.g., Cu, very strongly, so that small amounts of such elements added over a long period could account for relatively high contents of these elements in the peat.

TABLE III

Trace Element Contents of the Ash and of Pieces of Rocky Material from
Sample E.

(as parts per million)

| | Sample E ash | Sample E ¹ rocky material |
|----|-----------------|---|
| Ga | 7 | 20 |
| Cr | 300 | 200 |
| Ti | 700 | 1500 |
| V | 60 | 100 |
| Mo | 10 | <1 |
| Li | 1? | 10 |
| Ni | 60 | 150 |
| Co | 15 | 20 |
| Cu | 200 | <10 |
| Sc | 15 | 10 |
| Zr | <30 | 30 |
| Mn | 2000 | 600 |
| Y | 15 | 10 |
| Ag | 3 | <1 |
| Sr | 700 | 250 |
| Pb | 10 | <10 |
| Ba | 15 | 150 |
| Rb | 1 | 20 |

COMPARISON OF TRACE-ELEMENT CONTENTS OF VARIOUS PEAT SAMPLES

In Table 4, the trace-element contents (in parts per million referred to ash) of samples of peats from Finland, North Norway, Central Ireland and North Scotland are set out. It should be noted that the results in columns (a), (b) and (c) refer to samples which are from areas near ore-deposits, and so the values for some elements tend to be rather higher than might occur in areas away from ores. The results in column (d) are only qualitative. Hence, the main comparisons will be between the Scottish peats in column (e) and the Macquarie samples in column (f). There are some striking similarities in trace-element contents, e.g., V, Ni, Co and Sr. The Scottish samples are somewhat higher in Ti, Pb and Ba, slightly higher in Mo and Cu, but lower in Cr and Mn. The low Ba in The Macquarie samples have a high ratio of Sr to Ba, namely 20-45, compared with 2-3 for the Scottish ones. Although Pb was detected in the Macquarie samples it is considerably less than the 80-320 p.p.m. found in the Scottish samples. This is not so surprising when one realises that surface soils from the north-east of Scotland contain about 20-550 with a mean of 70 p.p.m. Pb (Swaine, 1951, 1955).

TABLE IV
Trace Elements in Peat Ash from Surface Samples.

(as parts per million)

| | (a) Finland | (b) North Norway | (c) Finland | (d) Central Ireland | (e) North Scotland | (f) Macquarie Island |
|-----|----------------|------------------------|------------------------|---------------------------|--------------------------|----------------------------|
| Ash | 0.6, 2.1% | — | 2.9-55.9% | — | 2.1-3.9% | 15-22% |
| Cr | <100 | — | — | — | 20-30 | 200-300 |
| Ti | — | — | <500-3300 (1000) | — | 4100-5600 | 500-1000 |
| V | — | — | <10-2600 (170) | — | 70-90 | 60-100 |
| Mo | — | — | <10-50 (7) | — | 25-35 | 5-15 |
| Sn | —, 60 | 30 | <10-100 (15) | + | <50 | <10 |
| Li | — | — | — | (+) | — | <1-1? |
| Ni | 30, 60 | 300 | <10-1000 (70) | — | 65-100 | 60-150 |
| Co | 10, 30 | 100 | <10-700 (60) | — | 15-20 | 15-25 |
| Cu | 300, 1000 | 1000 | <100-2000 (350) | + | 90-630 | 200 |
| Mn | 300, 300 | 600 | 30-10000 (1850) | ++ | 110-540 | 600-3000 |
| Ag | — | — | <10-c. 10 (<10) | + | — | 2-3 |
| Sr | — | — | — | + | 540-1140 | 700-1000 |
| Pb | 600, 1000 | 100 | <10-4000 (200) | + | 80-320 | 10 |
| Ba | — | — | — | (+) | 380-410 | 15-50 |

(+) denotes faint but detectable trace.

— means not determined.

(a) 2 samples from peat bogs (near ore-deposits) — Salmi (1950).

(b) 1 sample (near Cu-ore) — Salmi (1950).

(c) 45 samples for V and Ti, 27 for others (mean values in brackets; near ore-field) — Salmi (1955).

(d) 1 sample — Webb & Fearon (1937).

(e) 3 samples — Mitchell (1954).

(f) 3 samples (this paper — nos. D-F).

SUMMARY

The samples of peaty soils and morainic material had pH values of 4.6-6.9, with ash values of 15-61% for the former and 92%, 97% for the latter. Mineralogical examination of the morainic materials indicated that they are probably doleritic. The sample of basaltic rock has lower potassium and phosphorus contents than an average Pacific Islands basalt and Daly's average basalt. In keeping with their basic character, the rock and morainic materials are low in Zr, Pb, Ba and Rb. The peaty soils seem to have concentrated Mo and Cu appreciably and Mn, Ag and Sr slightly. The trace-element contents of the peaty soils have been compared with other peat samples from Finland, Norway and Scotland.

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