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NEW ZEALAND MICROCOSM OF SUBTROPICAL SOILS

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Abstract

Some examples of zonal soils in New Zealand are described by a visiting Soviet soil scientist. Analyses made in Moscow of samples colected during the visit are given and compared with results obtained by New Zealand Soil Bureau. The soils are correlated with some soils in Transcaucasia and alternative methods of classification are proposed.

INTRODUCTION
by
H. S. Gibbs, New Zealand Soil Bureau

In November 1962, Professor I. P. Guerassimov, and Dr A. A. Erokhina of the Institute of Geography, University of Moscow, visited New Zealand for a Joint Meeting of the Commissions 4 and 5 of the International Society of Soil Science. In addition to attending conference sessions at Palmerston North, they made several field excursions through parts of New Zealand, and during these excursions they studied numerous soil profiles, and the associated pedological data of New Zealand soil scientists. An immediate report on their visit was published in *Pochvovedeniye (Soviet Soil Science)* for April 1963 and included reference to a draft report on the geographic analogy of soils of Caucasus and New Zealand. During their field excursions the two Soviet scientists collected soil samples which were sent back to Moscow. After the analyses were completed in 1967 Professor Guerassimov finalised his paper on his observations on the soils of New Zealand and compared them with soils that he knows in the Caucasus region of Russia.

The general geographical characteristics of the territory of New Zealand, the wide variety of soils, and the broad concepts of New Zealand pedologists on the nature of soils are briefly set out in *A Descriptive Atlas of New Zealand* (McLintock 1960). They encourage me to compare details and to establish the similarities and differences in the genetics and geography of these soils in one of the most interesting soil subtropical "microcosms" — oceanic New Zealand — with an Eurasian intracontinental "microcosm" — Soviet Transcaucasia. Geographical grounds for such a comparison are obvious. First of all, there is a great similarity in geographical latitudes (34° - 47° S. Lat. for New Zealand and 47° - 39° N.Lat. for the Caucasus). Secondly, the close analogy in mountain-plain relief with a predominance of mountainous and hilly expanses, the distinct vertical zonality of natural conditions and great contrasts in climatic humidity or aridity due to coastal and intermontane location of separate areas in New Zealand or Transcaucasia, and the role of "wind-shadow regions" in the climate of certain territories.

Considering the available information about the soils of New Zealand, such a geographical problem becomes especially attractive. Even the rather original and distinctive soil nomenclature established in New Zealand (yellow-brown earths, brown-grey earths, red and brown loams etc.) prompts certain close or distant soil-geographical and genetic analogues. Of course, for many geographical reasons, and for differences in methodological approach and nomenclature traditions of scientific schools, such a comparison needs to be carefully done.

Despite all the theoretical allurement of such an enterprise, I probably would not have undertaken it if I had not had a chance during my field excursions to see the greater part of zonal and intrazonal soils distinguished by New Zealand pedologists in the field and to compare them with soils that I had studied personally in Soviet Transcaucasia. So, in the North Island: north of Auckland City, we had excursions within the region of northern yellow-brown earths, northern podzols, and red and brown loams; and in its central part north of Palmerston North City within the region of central yellow-brown earths, central yellow-grey earths, yellow-brown loams and made a trip to a vast field of yellow-brown pumice soils. In the South Island we travelled across areas of southern yellow-grey earths, crossed ranges of high country yellow-brown earths, and saw brown granular loams and even alpine soils.

Below are given the main results of field observations during our New Zealand excursions, as well as analytical data obtained from laboratory treatments of the samples we brought home to Moscow. These results of analyses are supplemented by New Zealand data relating to the particular profiles studied by us in the field and extracted from New Zealand published material (N.Z. Soil Bureau, 1968).

We begin the presentation of our data by describing a soil profile within the extensive region of the central yellow-brown earths in the North Island. This profile is at Taita 15 miles north of Wellington on the experimental station of the New Zealand Soil Bureau. Owing to local conditions of occurrence, this particular profile (Taita clay loam) is not very extensive though it was recognised by New Zealand pedologists to be a strongly leached, deeply weathered central yellow-brown earth. Here is a description of this profile.†

The profile is on a terraced bench of the lower part of a mountain slope under a dense growth of shrubs and young conifer trees. This is an obviously secondary vegetation in place of a felled beech forest *(Nothofagus truncata)* with a great share of evergreen trees. The top soil horizon (0-20 cm) is greyish yellowish brown loam, blocky-lumpy, rather loose and light coloured in the dry state. Below 20 cm comes a much more compact and uniform mass of yellowish brown loam, with brown faces on the block surfaces. Further down, at a depth of 80-140 cm, there is a loamy soil mass, still compact, that has an uneven reddish yellow colour, determined by the appearance of reddish spots which progressively get larger and larger. At a depth of 140 cm the soil is underlain by weathered parent rock — weathered fragments of greywacke in a clay deluvium. Near the soil profile, in a shallow quarry at the foot of the slope, there are outcrops of a fresh, unweathered greywacke rock.

Tables 1 and 2 give results of chemical analyses of samples from this section obtained at the Institute of Geography of the Academy of Sciences of the USSR.

Table 1 indicates that the soil mass has a weakly acid reaction, is highly humified in the upper part, is loamy with a markedly greater silt* content in the lower part; it has a low base exchange and a large amount of exchangeable hydrogen (or Al ?).

† Profile descriptions are limited to notes made during a rapid inspection.
* The 0.005 - 0.001 fraction in USSR.

Table 1. Analyses (U.S.S.R.) of Taita clay loam.

Depth of Samples cm	pH Water	pH Salts	Humus %	Size Distribution % 1–0.01 mm	0.01–0.005 mm	0.005–0.001 mm	<0.001	Cation Exchange Ca me%	Mg me%	H me%
0–20	5.1	4.5	7.2	54.7	8.8	19.0	4.7	3.8	1.7	26.4
60–80	4.9	4.4	1.5	45.7	8.0	22.8	18.9	2.7	1.1	19.6
120–140	4.8	4.4	0.6	50.3	5.3	29.0	11.4	–	–	–

Table 2. Analyses (U.S.S.R.) of Taita clay loam.

Depth of Samples cm	Ignition losses %	Total content SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	SiO_2/R_2O_3	SiO_2/Al_2O_3	SiO_2/Fe_2O_3
0– 20	10.2	79.6	12.4	3.3	1.0	1.7	9.3	10.9	63.7
60– 80	9.6	60.0	29.2	7.5	0.6	1.0	3.0	3.5	21.3
120–140	6.8	63.5	19.8	6.6	0.5	1.2	4.5	5.4	25.4
rock	–	70.9	16.3	2.8	1.7	0.9	6.7	7.4	69.1

Table 3. Analyses (N.Z.) of Taita clay loam.

Depth of Samples cm	pH H_2O	pH KCl	Carbon %	Size Distribution % 2–0.02 mm	0.02–0.002 mm	<0.002 mm	Cation Exchange Capacity me%	Total cations me%	Base /Satn. %
0– 5	4.7	3.6	4.9	26	34	39	18.7	7.3	39
5–22	4.9	3.7	1.6	12	21	67	18.2	5.0	28
22–37	4.9	3.8	1.3	16	22	62	18.1	3.0	17
37–50	4.9	4.0	0.8	14	20	65	14.9	1.3	9
50–70	5.0	3.9	0.6	19	23	58	16.0	1.3	8

The results of total analyses (Table 2) establish a rather distinctly expressed relative increase in SiO_2 content in the upper horizon of the soil, even greater than in the rock. On the other hand, the sesquioxides (Al_2O_3 and Fe_2O_3) obviously accumulate in the lower part of the soil. CaO and MgO show a certain accumulation in the top sample as compared with the underlying samples.

In this way, though analysis does not give any evident signs of lateritisation (allitisation) of the profile, the low base exchange capacity for Ca and Mg might indicate this fact. More indisputable is soil differentiation by silt; this might be the result of lessivage (inwash of non-destroyed silt) which is not very probable, judging by the environmental conditions of the soil. More probably it seems that this feature reflects the podzolisation of this soil. Our field determination of this profile does not contradict the analytical data which are that this is a yellow-brown forest subtropical soil, possibly podzolised and partly eroded.

The above-given analytical data compared with the New Zealand analyses of this soil (Table 3) do not change the above conclusions. One point that deserves attention is a much higher yield of silt in New Zealand determinations as compared with our figures. This discrepancy may be explained by a difference in methods used and by the differing range in size fractions.

Let us mentally "move" now to the northern part of the North Island and review data on three somewhat differing profiles of northern yellow-brown earths. These soils are No. 8 (Waikare silty clay loam), No. 7 (Whangaripo clay) and No. 6 (Puhoi clay loam). In New Zealand all of them are termed "northern yellow-brown earths" (American synonym — red-yellow podzolic soils), but with a varying degree of leaching: No. 8 strongly leached, No. 7 moderately leached, and No. 6 weakly leached. Brief morphological descriptions of these soils made by us in the field are as follows :

Profile No. 8 (Fig. 1) Eluviated site, elevation 90 m., gentle slope of 12°, planted Monterey pine *(P. radiata)* with local remains of original Kauri *(Agathis australis)* forest, grasses and *Leptospermum* sp. *Juncus polyanthemos* and other plants.

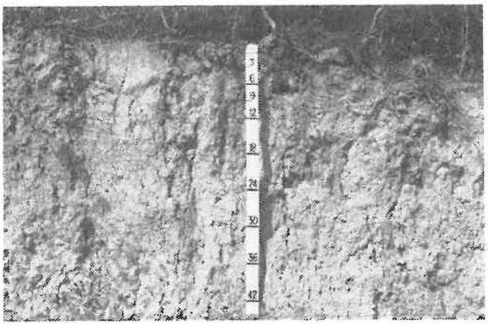
1. 0-18 cm Humus horizon of a dirty whitish grey loamy clay; rather compact; distinct nutty-lumpy structure.
2. 18-50 cm Bright yellowish brown clay with red spots; blocky-nutty; compact.
3. 50-90 cm Clay with an uneven colouring, of large bright red spots on a yellowish brown background; blocky.
4. 90 cm and deeper. Bluish reddish yellow clay from deeply weathered rock that preserves its structure (lithomarge).

Profile No. 7 (Fig. 2). Dissected elevation with nearly deforested slopes. The profile is on a slope of 12°, at the present time covered with dense growths of *Pteridium esculentum* ferns. On the same slope there are, however, patches of pines *(P. radiata)* and remains of the original vegetation consisting of *Podocarpus* sp. and others.

1. 0-14 cm Humus horizon; weakly expressed sod in the upper part, over light yellowish brown clay loam; blocky-nutty and lumpy.
2. 14-50 cm Yellowish brown loamy clay; blocky-lumpy; cleavage faces are darker (humus incrustations ?).
3. 50-100 cm Yellowish brown clay, with red spots; blocky.
4. 100-150 cm Reddish brown deeply weathered rock that retains its structure.

Profile No. 6. Coastal hilly territory; elevation 90 m., slope 8-10°; after felled forest with single trees (*Podocarpus* sp.) on a pasture predominantly *Dactylis glomerata, Festuca arundinacea, Paspalum dilatatum, and Lotus major.*

1. 0-20 cm Humus horizon of loamy clay; rather compact; lumpy-nutty structure.
2. 20-40 cm Yellowish brown, with higher clay content and more compact; prismatic; nutty; rare rusty red spots.
3. 40-80 cm Variegated (bluish, red, brown spots) loamy clay; prismatically blocky.



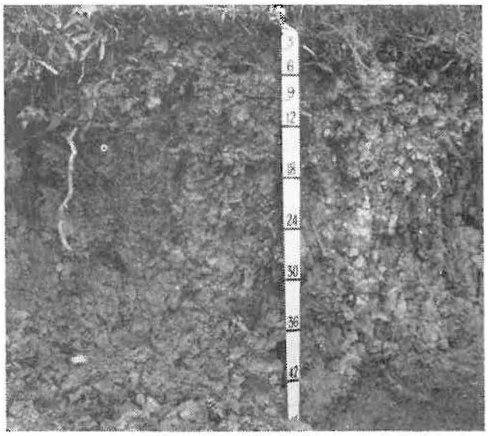


Figure 1 Soil Profile (No. 8) Waikare silty clay loam near Wellsford, North Auckland. *Photo: H. S. Gibbs*

Figurе 2 Soil Profile (No. 7) Whangaripo clay near Warkworth, North Auckland. *Photo: H. S. Gibbs*

Table 4. Analyses (N.Z.) of Waikare silty clay loam (No. 8) of Whangaripo clay (No. 7) and of Puhoi clay loam (No. 6).

Profile No.	Depth of Samples cm	pH Water	Carbon %	Size Distribution % 2–0.02 mm	0.02–0.002 mm	<.002 mm	Capacity me%	Base %	Cation Exchange Ca me%	Mg me%	Na me%	K me%
8	0– 8	5.2	3.8	17	38	45	18.3	51	5.2	3.4	0.4	0.5
	8–20	5.1	1.2	2	37	61	15.2	23	1.3	1.6	0.2	0.3
	20–84	4.9	0.8	10	25	65	17.8	16	0.5	1.8	0.2	0.2
	84	4.7	0.4	16	24	60	21.2	9	0.4	1.1	0.2	0.2
7	0– 8	5.8	6.1	30	26	44	27.8	59	9.6	6.3	0.3	0.6
	10–18	4.9	2.8	13	28	59	15.9	23	1.6	1.9	0.1	0.3
	23–43	4.7	1.7	19	28	53	16.2	12	1.1	1.1	0.1	0.2
	51–86	4.6	0.8	14	23	63	18.9	7	0.7	0.3	0.2	0.1
6	0– 8	5.5	6.2	27	26	47	31.2	66	9.5	9.1	0.4	1.6
	13–18	5.2	3.0	–	–	–	23.0	55	4.6	5.9	0.2	0.8
	24–46	5.1	1.3	25	26	49	25.0	41	3.2	6.6	0.4	0.6
	56–71	5.0	0.5	26	28	46	28.9	39	1.3	9.2	0.4	0.3

Table 5. Analyses (U.S.S.R.) of Timaru silt loam.

Profile No.	Depth of Samples cm	pH Water	pH Salts	Humus %	Size Distribution % 0.05–0.01 mm	0.01–0.005 mm	0.005–0.001 mm	<0.001 mm	Cation Exchange Ca me%	Mg me%	H me%	Al me%	Mobile iron* %
10	0– 10	5.8	4.2	7.3	70.5	6.5	16.8	5.0	5.1	3.6	19.0	0.9	0.69
	40– 50	5.7	4.1	0.9	65.2	7.3	9.9	16.4	4.1	1.9	15.3	1.0	0.91
	80– 90	4.2	3.7	0.4	64.7	10.7	6.1	16.7	3.9	1.9	19.4	4.8	1.05
	400–420 (pseudo-loess)	5.4	4.5	0.3	65.1	10.1	8.7	14.1	4.3	3.1	11.0	4.6	1.04

* According to the method of Aguilera and Jackson 1953.

In Table 4 are New Zealand analyses for these three profiles. Summarising the above-given morphological descriptions and analytical data, we get the following general impression.

The major properties of all three profiles are in fact of the same type. These are subtropical soil forms developed on a lateritic (allitic) crust of weathering of sedimentary sandy-clay rocks (of a flysch type) altered into lithomarge. Previously, forest subtropical soils were developed on this crust of weathering. However, after (or in the process of) deforestation the upper soil was to a great extent eroded, and on its "roots" (or directly on the lithomarge), the modern "active layer" of soil formation was developed (I. P. Guerassimov and A. I. Romashkevich, 1967). The extent of development of the "new" soils varies substantially. Profile No. 8 is apparently the least developed and where less humus has been accumulated; the degree of saturation in exchangable cations introduced here in the process of the biological cycle of the matter is relatively low and shallow. In this respect the relatively most developed "new" soil is represented by Profile No. 6.

Crusts of weathering and soils of this kind typical for the humid subtropical areas of Soviet Transcaucasia, are called "zheltozems-kraznozems". We find it necessary to make a difference between them and the subtropical forest yellow-brown soils, with which are identified the Taita profile (see above). In a similar manner to the New Zealand pedologists, we think also that it is necessary to distinguish between central and northern yellow-brown earths of New Zealand; one of the main criteria in this distinction being the extent and depth to which the lateritic (allitic) crust of weathering is developed. In the yellow-brown forest subtropical soils the crust, in practice, coincides with the "active layer of soil formation", which means that in the profile of these soils we rarely see the subsoil lithomarge (or the true crust of weathering); in the profiles of zheltozems-kraznozems there is always a thick lithomarge (2-3 m. thick as a minimum) on which modern soils are developed, the primary or secondary forest soils being washed off in the process. Consequently it follows that in the classification of central yellow-brown earths (yellow-brown forest subtropical soils) and the northern yellow-brown earths (zheltozems-kraznozems) we find a complete analogy between New Zealand and Soviet Transcaucasia.

On our excursions in the South Island we found a completely different situation. Our field excursion visited only the eastern part that has been forestless for some centuries. This is in contrast to the western part of the South Island and the greater part of the North Island. Unfortunately, for reasons of distance and of time, our tour did not include the western forest part of this island so we did not see the New Zealand podzols and podzolic soils mapped there. Consequently this review will not attempt to make any comparisons between New Zealand podzols and the subtropical "pseudo-podzols" of Soviet Transcaucasia.

We begin the summarisation of our field data for the eastern part of the South Island with a description of soil profile No. 10 near the town of Timaru in the middle part of an extensive soil region called southern yellow-grey earths by New Zealand pedologists and located in cool and mild subhumid areas.

This profile is located on an undulating coastal plain consisting of lava covered by a thick mass of drift, extremely similar to loesses. An excellent 8 m. thick exposure of these "pseudo-loesses" was located in a brick quarry near the railway station of Timaru. A sample of the "pseudo-loess" has been analysed (see sample from 400-420 cm in Tables 5 and 6). The elevation of the section is about 20 m. above sea level, vegetation is sown meadow (pasture) of *Agropyrum repens* after the original vegetation of silver tussock *(Poa caespitosa)*. A description of the profile (No. 10) is:

1. 0-30 cm Humus horizon, dark grey dusty loam with a poorly expressed sod: unstable lumpy-granular structure.
2. 30-50 cm Yellowish brown with small rusty spots, compact dusty loam, with a weak structure (in practice structureless).
3. 50-70 cm Lighter and more compact than the overlying; more intensely gleyed; in addition to small ferruginous spots also numerous larger bluish spots.
4. 70-120 cm Light brown very compact "pan" of cemented loam with less distinct features of gleying — diffused rusty spots.
5. 120-150 cm and deeper. Somewhat less compact, gradually changes into "psuedo-loesses".

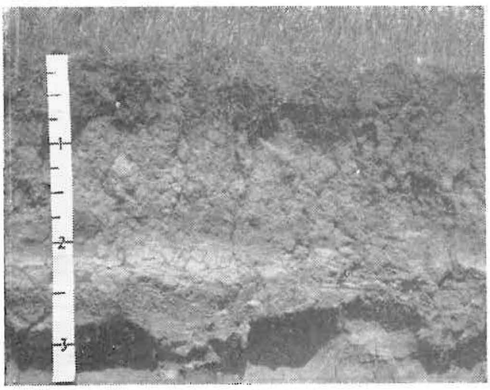
The New Zealand classification is moderately leached southern yellow-grey earth and a profile is illustrated in Fig. 3.

Table 6. Analyses (N.Z.) of Timaru silt loam.

Depth of Samples cm	Ignition Losses %	Total content					$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$
		SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %			
0– 10	9.1	74.4	13.5	3.5	2.2	1.2	8.1	9.4	57.1
40– 50	3.2	72.2	15.1	3.7	1.9	1.3	7.0	5.2	51.6
80– 90	2.1	71.7	14.9	3.7	2.1	1.1	7.0	8.1	51.6
400–420	2.3	72.2	15.0	3.7	2.5	1.2	7.1	8.2	51.8

Table 7. Analyses (N.Z.) of Timaru silt loam.

Depth of Samples cm	pH		Carbon %	Size Distribution %			Cation Exchange			
	H_2O	KCl		2–0.02 mm	0.02–0.002 mm	<0.002 mm	Ca me%	Mg me%	Base Satn %	Capacity me%
0–10	4.1	4.7	4.6	35	44	21	5.0	3.4	47	17.2
30–45	5.8	4.4	0.8	41	42	17	2.9	2.4	48	10.6
45–55	5.7	4.0	0.6	44	38	18	2.5	2.0	40	11.5
60–90	5.3	3.6	0.4	–	–	–	1.5	1.6	28	11.8



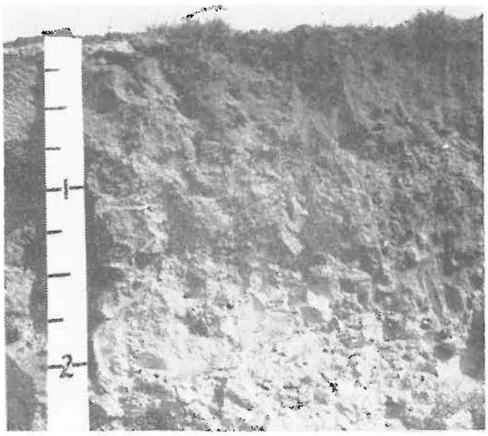


Figure 3 Soil Profile (No. 10) Timaru silt loam near Timaru, South Canterbury.
Photo: E. J. B. Cutler

Figure 4 Soil Profile (No. 11) Conroy sandy loam near Alexandra, Central Otago.
Photo: E. J. B. Cutler

Tables No. 5 and No. 6 give the results of our analyses. At first I thought the results of analytical determinations to be erroneous. Despite its "arid" morphological appearance the soil proved to be weakly acid; sandy-dusty, without any signs of "claying" in the consolidated "pan" horizon; highly unsaturated, and in the lower part (even in the "pseudo-loess") with a substantial content of exchangable aluminium. However, the content of "mobile" iron (determined according to the method of Aguilera and Jackson 1953) proved to be comparatively low.

The results of a total analysis (Table 6) also demonstrated the deep specific properties of this soil. It is obviously acid by its petrographic composition, the chemical composition changing only very slightly throughout the profile (except the uppermost humus horizon); the consolidated ("pan") horizon virtually does not differ from the rock ("pseudo-loess") and the overlying horizon.

By inspecting New Zealand analysis (Table 7) it was obvious that the general analytical characteristics obtained by us fully correspond to those of New Zealand (pH is even lower — 4.1; the amount of silt is small and stable; the base status is not high). It was simultaneously found that the mineralogical composition of the soil-dust fraction contains a great amount of volcanic glass and could mean that the parent rock of this soil is volcanic ash of a rhyolitic composition. (This was a theory advocated by Goodall (1886) but subsequent review of evidence and detailed mineralogical examination by Raeside (1964) strongly favours origin as loess.)

As a whole, the soils proved to be really very original. Despite a weakly acid reaction and low saturation due, apparently, to intense leaching, the soil is very "stable" in its mineral mass, i.e., it is not (significantly) affected by decomposition and migration of its mineral components. A distinct compactness in the lower part that stimulates features of internal stagnation of soil moisture (gley features in the layer of 50-70 cm), finds no expression in silt accumulation (not mentioning the carbonates); in other words it is a purely structural formation. Notes in my field diary indicate that the compaction was associated in my mind with manifestations of some buried periglacial phenomena.

Then we proceeded to investigate and describe a most interesting series of soil profiles in the vicinity of the town of Alexandra in Central Otago. On the soil map of the South Island this area is entirely within an extensive region of cold and semi-arid climate. In fact the New Zealand description of the main profile (No. 11) of this series says that this profile is at an elevation of 260 m above sea level; the January mean temperature of the summer of 16° C, and a mean July winter temperature of 2° C with a yearly precipitation total formed on a solifluction "loess-like" drift and illustrated in Fig. 4.

The morphological description of profile No. 11 is:

Lower part of the flank of a small hill close to the town of Alexandra; vegetation — meadow steppe (tussock).

1.	0-30 cm	Pale grey rather compact, porous loam, with an indistinct platiness.
2.	30-45 cm	Greyish brown, more compact loam; large blocks with brown spots on the blocks, vertically jointed.
3.	45-55 cm	Gradually gets paler and changes into a light coloured, dusty-marly horizon with shale rubble.

A small distance away another profile (No. 14) was located in a little depression and also on a solifluction drift with shale rubble, under a patchy grass vegetation consisting of *Hordeum maritimum, Atriplex* sp., etc. A description of profile No. 14 is:

1.	0-15 cm	Brownish grey with rusty spots; compact loam; prismatic blocky structure.
2.	15-30 cm	Very compact brown loam; blocky with brown faces on the blocks.
3.	30-60 cm	More loose and paler large blocks with dark humus sinter along the faces of the blocks.

Table 8. Analyses (N.Z.) of Conroy sandy loam (No. 11), of Manorburn sandy loam (No. 14), and of Lowburn loamy sand (No. 15).

Profiles	Depth of Samples cm	pH H₂O	pH KCl	Carbon %	Size Distribution % 2–0.02 mm	Size Distribution % 0.02–0.002 mm	Size Distribution % <0.002 mm	Cation Exchange Capacity me%	Cation Exchange Ca me%	Cation Exchange Mg me%	Cation Exchange K me%	Cation Exchange Na me%	Stones %
11	0– 8	5.8	4.9	0.7	60	24	16	5.7	2.8	1.0	0.5	0.5	
	10–28	5.4	4.2	0.5	50	30	19	4.5	2.2	1.0	0.4	0.4	
	28–41	8.0	7.2	0.3	42	25	17	4.3	2.5	0.7	0.1	0.1	
	41–61	8.6	7.5	0.3	60	23	17	18.8	10.0	3.4	2.9	2.9	
14	0– 5	6.2	–	1.7	66	23	11	7.3	3.3	2.2	0.7	1.0	
	5–10	5.9	–	1.2	64	22	14	6.2	1.7	2.6	0.5	1.3	
	10–20	6.8	–	0.4	57	20	16	5.3	1.8	2.6	0.5	1.3	
	20–29	7.4	–	0.3	56	10	13	4.7	1.7	3.0	0.4	1.5	
	33–38	8.3	–	0.2	–	–	–	7.5	–	5.5	0.3	1.9	
15	0–10	5.9	–	2.0	75	17	8	6.1	2.0	0.8	0.4	0.1	–
	12–41	5.8	–	0.3	82	11	4	4.0	2.1	0.7	0.1	0.0	39
	43–61	6.6	–	0.2	35	15	10	9.3	8.0	2.3	0.2	0.2	39
	71–91	7.2	–	0.1				5.4	6.1	1.5	0.1	0.1	47

Table 9. Analyses U.S.S.R.) of Conroy sandy loam (No. 11) and of Manorburn sandy loam (No. 14).

Profile No.	Depth of Samples cm	pH Salts	pH Water	Humus %	Size Distribution % 0.25–0.01 mm	Size Distribution % 0.01–0.005 mm	Size Distribution % 0.005–0.001 mm	Size Distribution % <0.001 mm	Cation Exchange Ca me%	Cation Exchange Mg me%	Cation Exchange H me%	Cation Exchange Al me%	Mobile iron %
11	0– 5	4.4	5.6	2.3	74.8	5.4	5.9	7.5	4.1	1.4	19.0	0.9	1.1
	10–20	5.1	5.5	1.0	73.9	2.2	10.6	7.3	2.4	1.7	19.4	0.5	1.3
	30–40	5.0	6.3	0.5	65.9	5.6	6.0	15.8	4.3	2.5	16.1	0.3	2.1
	65–75	–	–	0.3	–	–	–	–	–	–	–	–	1.1
14	0–10	4.4	5.4	2.8	61.1	10.0	11.3	12.0	5.8	2.4	16.6	0.4	1.2
	20–30	5.0	5.9	0.7	49.8	7.7	10.4	23.6	4.1	4.4	13.4	–	1.4
	40–50	4.7	5.5	0.4	15.9	17.6	33.0	18.4	4.2	–	14.6	0.9	0.5

According to the New Zealand classification profile No. 11 is a brown-grey earth, and profile No. 14 is a solonetzic soil associated with brown-grey earths. New Zealand analytical data for these profiles is included in Table 8 and our results are set out in Tables 9 and 10.

Data in Table No. 8 give a very peculiar picture. By their reactions the top parts of soil No. 11 and 14 are acid; the lower parts have an alkaline reaction; the humus content in soils is low; texture is dusty-sandy with a small amount of silt. The total absorbing capacity and amount of exchangeable cations are quite low in the upper part of the soil mass; however, in the lower sample (subsoil ?), the capacity and amount of exchangeable cations increase sharply. These data may not be quite reliable because of inaccuracies in the methods used for determinations in the alkaline sample.

Generally speaking, data of Table 9 confirm the above characteristics and might even stress them a bit. Thus, in respect to pH values both soils prove to be weakly acid; this is confirmed by the determination of exchangeable hydrogen. The amount of exchangeable aluminium is, however, small; not high also is the content of "mobile" iron.

Data of Table No. 10 indicate that the soil studied has, apparently, a siallitic composition of its mineral mass. The changes in SiO_2/R_2O_3 ratios have no distinctly expressed illuvial regularity except possibly with the distribution of silt particles in the soil profile (see Table 9).

Before making any general conclusions, three more soil profiles in the same region of the town of Alexandra will be described. One of them (No. 15) is located near the aerodrome, on the surface of a high old terrace under a cultivated meadow with an irrigation system. The soil is developed on pebbles; its mass consists of pebbles mixed with silt. The soil profile is divided into two parts:

1) a finer silt 30 cm thick and,
2) a more sandy-gravelly part underlying the first one.

On such a two-member drift a soil is developed consisting of a humus layer of 10 cm grey loam, comparatively loose; 30 cm greyish light yellow horizon, more compact; then a coarser sandy-pebble mass with humus-ferruginous and calcic films and patches down to a depth of 1.5 - 2m.

In general, the analysis of profile No. 15 (Table 8) demonstrates the same features of the investigated soil as profile No. 11. Even despite a sandy-gravelly soil composition, the upper samples have a weakly acid reaction, while the lower samples have a neutral reaction, the entire soil containing a small amount of exchangeable cations. Though the texture is coarser, towards the bottom (43 - 61cm) the soil becomes weakly alkaline and its exchange capacity increases considerably.

Near Alexandra we ascended to the summit of a small mountain (Old Man Range) with an absolute height of 2000m. Along the route we observed a distinct vertical change in natural landscapes. Three main belts could be

Table 10. Analyses (U.S.S.R.) of Conroy sandy loam.

Profile No.	Depth of Samples cm	Total Content SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$
11	0– 5	70.0	15.3	4.8	2.0	1.6	6.5	7.8	38.7
	10–30	69.3	15.7	5.4	2.2	1.4	6.2	7.5	34.3
	30–40	63.1	16.5	9.8	2.1	1.6	4.7	6.5	17.1
	65–75	63.7	12.5	6.3	4.6	1.8	6.3	8.6	27.0

distinguished. In the lower belt with an atmospheric precipitation of 300-400 mm and within which profiles 11, 14, and 15 were located there is an open landscape with a sparse grass cover. This belt can be traced up to between 400 - 500m. Higher up from 400 - 500 to 1500m. and a precipitation exceeding 500cmm the grass cover becomes higher and denser. However, its composition is characterised, as before, by a predominance of sedge and sod grasses, though we find here separate sparse small woods of a xerophytic tree *(Discaria toumatou)*. In this belt profile No. 13 was located on a bench of a mountain slope under the following vegetation: *Danthonia* sp., *Poa* sp., *Festuca* sp., *Aciphylla* sp. etc.

The morphological profile of soil No. 13 is:

1. 0-20 cm Humus horizon, weakly expressed; greyish brown dusty loam; loose-lumpy structure.
2. 20-40 cm Brown (with a yellowish tint) weakly structured, somewhat consolidated loam.
3. From 40 cm downwards a brown loam with fragments of slightly weathered shale rubble, their number rapidly increasing.

According to New Zealand pedologists this soil profile belongs to the Arrow set and is classified as a southern yellow-grey earth.

Further up, at a height of about 1400-1500 cm, the amount of precipitation comes to 1000 mm, and in the composition of grass vegetation there is a predominance of *Danthonia rigida* (snow tussock), *Poa colensoi* (blue tussock), *Festuca mathewsii* and *F. novozelandica*. Coming to the surface of the flattened-out summit, we saw a peculiar "tor" landscape on which columnar outcrops of shales stand out sharply amongst fields of stones, and obviously of a periglacial nature.

Profile No. 12 was located at a height of 1900 mm; precipitation here comes to 2000 mm; vegetation was cushion plant formations with moss and lichens and consisting of *Dracophyllum prostratum, Raoulia grandiflora, Myosotis* sp., *Celmisia sessiflora, Hectorella* sp., *Pygmea* sp.

In general the landscape represented vast stone fields. A description of the soil profile (No. 12) is:

1. 0-5 cm Thin humus horizon; slightly peaty; brownish black.
2. 5-15 cm Rapidly becoming paler with a somewhat yellowish tint; weakly expressed structure of small lumps; much rubble.
3. 15-40 cm Bluish yellow brown loam with abundant rubble.

New Zealand pedologists include this soil in the Obelisk set and classify it as a very strongly leached high country yellow-brown earth. Table 11 gives analytical data for both profiles described and shows that both soils have an acid reaction; substantial humus accumulations have been recorded; they are sandy-stony (very small amounts of silt) and highly unsaturated.

Table No. 12 gives the results of total chemical analyses and they indicate that the mineral part of both soils reveals only minor changes of its chemical composition.

According to the classification of New Zealand pedologists, the series of soil profiles studied in the region of Alexandra (together with profile No. 10) represent three different genetic types of soils (brown-grey earths, yellow-grey earths, and high country yellow-brown earths), but judging by our data, they form one geographical-genetic chain of peculiar soils. In my field diary I made a note that this is a special group of soils with an unstable reaction — from neutral to weakly acid and acid. All soils of this group, despite a dry climate in the plain part of the territory, are substantially leached; only with impeded drainage (profile Nos. 14 - 15) does the reaction of their lower part change — becoming average or even alkaline (profile No. 15) and an accumulation is recorded of soluble carbonate salts. At the same time the mineral part of all these does not show signs of a marked destruction; it is poor in silt particles,

Table 11. Analyses (U.S.S.R.) of Omarama soil (No. 13) and Obelisk soil (No. 12).

Profile No.	Depth of Samples cm	pH		Humus %	Size Distribution %					Cation Exchange				Mobile iron %
		Water	Salts		1–0.25 mm	0.25–0.01 mm	0.01–0.005 mm	0.005–0.001 mm	<0.001 mm	Ca me%	Mg me%	H me%	Al me%	
13	0–10	4.5	3.4	5.4	3.2	65.8	10.2	12.0	6.3	8.1	0.7	36.4	4.1	1.67
	20–30	4.7	3.4	2.8	4.9	69.7	8.8	8.1	6.9	2.4	0.5	32.1	4.8	1.68
	40–50	4.7	3.6	1.8	8.9	66.6	4.4	7.8	10.5	2.4	–	23.4	–	2.42
12	0– 5	4.7	3.3	5.6	13.1	70.5	6.6	0.9	6.7	1.9	–	21.1	3.95	0.88
	15–25	4.7	4.0	1.1	13.8	75.5	3.7	1.4	2.3	1.0	–	16.4	0.6	1.16

Table 12. Analyses (U.S.S.R.) of Omarama soil (No. 13) and Obelisk soil (No. 12).

Profile No.	Depth of Samples cm	Total Content					$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$
		SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %			
13	0–10	68.8	17.9	4.5	1.3	1.1	5.6	6.6	41.1
	20–30	69.4	18.1	4.8	1.3	1.2	5.7	6.5	42.6
	40–50	68.8	15.9	5.3	1.3	0.3	6.0	7.3	34.7
12	0– 5	66.2	20.6	4.4	1.5	1.4	4.8	5.8	40.1
	15–25	64.9	18.4	5.3	1.5	1.5	4.8	5.7	32.8

the distribution of which does not display any features of displacement. All soils have a low base status; they contain a great amount of exchangeable hydrogen, small amounts of exchangeable aluminium. And yet morphological features indicate a substantial mobility of humus matter (especially in the upper zones) and, possibly, to a certain extent iron as well.

In this way one gets, first of all, a general impression of a certain genetic unity of all the soils described above from the South Island of New Zealand. Even the presence among them of soils with a well expressed consolidated horizon ("pan" in profile No. 10) does not change this impression, because this compact horizon does not record an accumulation of silt or lime. This is a purely morphological (structural) form, the genesis of which remains obscure. Maybe only the high country yellow-brown earth (profile No. 12), owing to its rudimentary nature and coarse composition of humus, stands somewhat apart from this single geographical-genetic series of soils.

It is notable that all the profiles described (again with the exception of No. 12) are developed under a peculiar grass vegetation called "tussock" in New Zealand. Of course, the extent to which this vegetation is developed (extent of surface coverage, density, biological productivity, etc.) is somewhat varied. It is more xerophytic in drier plain regions and somewhat more mesophytic in the middle mountainous belt. This would suggest a connection between such changes in the vegetation cover and some changes in the properties of their soils, as, for example, the amount of humus in them, the extent of leaching, etc. These differences, however, can still be included within the limits of systematic subdivisions of a single genetic type of soils.

On the basis of what has been said we do not see sufficiently valid arguments in favour of dividing soils 10, 11, 12, 13 and 15 into three independent genetic types of soils. On the contrary, as indicated in the arrangement of the New Zealand classes, I have the impression of a similar genetic character of all these soils, except for the Obelisk soils, which should be separated from the others. I think it possible to call the other soils (Timaru, Conroy, Lowburn and Omarama soils) *acid grey-brown soils under a tussock grass formation.* It is my view that the soil-forming process of these soils takes place under very peculiar conditions of a temperate-cold and relatively dry winter and a cool and arid summer with brief transition periods. Owing to these transition periods, these soils are leached; their biological cycle, however, is not intense; the destruction of the mineral mass also proceeds at a limited rate, though the highly mobile destruction products (water-soluble salts, first of all) are evacuated, as a rule, comparatively easily, beyond the limits of the soil profile. In this way, these soils are being formed under a certain insufficiency of both heat and moisture — two most important factors that determine the energy level of soil formation and the intensity of all its processes. For this reason, under existing conditions, these processes, though developed here rather evenly and harmoniously, are still somewhat incomplete, forming soils with a specific combination of main properties. I have not found similar soils yet in other countries and, in any case, analogues of these soils are completely absent in subtropical (and not only subtropical) areas of the USSR. The question arises — should in fact they be called subtropical? Maybe it is possible to do so only on purely formal geographical grounds.

CONCLUSIONS

Such are the main results of my field observations of the soils of New Zealand and the conclusions arrived at after a detailed analysis of these observations. They come down to the point that New Zealand pedologists are fully justified in distinguishing the main geographical groups of soils developed in their country. However, this subdivision, though geographically correct, is not sufficiently justified yet by a scientific genetic analysis, i.e. the establishment of the essence of biological, physical, and chemical phenomena that take place in the described soils and that are determining the similarities and differences in their properties.

That is why trying to distinguish, for instance, the "northern" and "central" yellow-brown earths on the North Island of New Zealand, the pedologists of this country do not regard such a division as a distinction between two independent genetic types of soils: yellow-brown forest subtropical soil on one hand, and zheltozems-kraznozems of humid subtropics (and tropics) on the other. That is exactly what we are doing for the territory of Soviet Transcaucasia. On the other hand, distinguishing geographical groups of brown-grey earths and southern yellow-grey earths of the South Island, the pedologists of New Zealand do not unite them into one original genetic type of *acid grey-brown "tussock" soils*. If such a unification is correct from a genetic point of view, it should be regarded as a justification of a new class of soils, quite endemic for the eastern part of the southern island of New Zealand. It is quite obvious, however, that the brevity of my stay on the territory of New Zealand and the limited scope of my field observations give my statements only the character of a scientific assumption, which demands verification and further justification.

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* Spelling in U.S.A. translation.