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The relationship between New Zealand's geology and soils and trace element deficiencies in grazing animals

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ABSTRACT

The soil type is an important factor influencing the occurrence of trace element deficiencies in grazing animals in New Zealand. Cobalt and selenium deficiencies occur mainly on soils from acidic rocks. Cobalt deficiencies may also occur on soils from more basic parent materials where the soils have been strongly leached. Selenium deficiencies are more likely if the soil is weakly weathered, poorly drained or strongly podzolised. The occurrence of copper deficiencies is less easily predicted on the basis of soil characteristics. Copper deficiencies are more likely in stock grazing on peat soils, gley soils, certain pumice soils, saline soils, recent soils and some steepland soils. For all 3 elements, classification of occurrences of deficiency by soil type has provided a basis for delineating areas where deficiencies are likely, areas where they are unlikely, and areas of marginal status. This has enabled a rational approach to investigations, and the application of treatment and control measures.

INTRODUCTION

The use of trace elements in pastoral farming is a cornerstone to maintaining high levels of animal production in New Zealand. 'Bush sickness', a wasting disease of sheep and cattle, virtually prevented settlement of the North Island's volcanic plateau, until the 1930s when the disease was discovered to be due to a lack of cobalt in the soil. In the 1940s a production limiting disease of cattle and sheep grazing reclaimed swamplands was recognised to be due to copper deficiency, and in the 1960s it was found that selenium deficiency was widespread in New Zealand, particularly on the weakly weathered soils from greywacke in the South Island.

The occurrence of these diseases in some localities, with other areas being free of the diseases, led to the early recognition of an association with the geology and soils of an area. Classification by soil type was immensely useful in delineating the areas of deficiency, predicting other areas where the deficiencies may occur, and in instituting control and preventive measures. There was close co-operation between workers in animal health and soil science, and indeed the incidence of 'bush sickness' gave considerable impetus to the development of the genetic soil classification and soil maps in New Zealand (Taylor *et al.*, 1956; Jackman *et al.*, 1962).

This paper briefly reviews the reported associations of geology and cobalt, copper and selenium deficiencies in grazing animals in New Zealand, and how a knowledge of geology and soils provides a basis for understanding the occurrence of trace element deficiencies in animals.

The Geological Basis for Trace Element Deficiencies

New Zealand has a wide array of soil types, which relates both to the diversity of parent rocks and the widely varying conditions for their transformation into soil. New Zealand lies on the interface of 2 active crustal plates, and the landscape and soils have been greatly influenced by mountain building, volcanism and erosion processes. In a general view most of the land surfaces of New Zealand were made either directly from volcanic materials of their erosion products. As molten rock or magma rises from the upper mantle into the earth's crust and cools, the first minerals to crystallise are networks of aluminum, silicon and oxygen held together by iron and magnesium together with associated trace elements such as copper, cobalt and molybdenum (ferromagnesians). These rocks are termed basalts or basic rocks. As the magma cools further, the rocks crystallising become lower in the content of ferromagnesians and thus of most trace elements. Andesites are next to form, followed by dacites and last to crystallise are rhyolites (for rocks erupted on the surface) and granites (beneath the surface). These last formed rocks are held together mainly by sodium, potassium and calcium and have the lowest content of trace minerals. They are termed acidic rocks because of their high silica content. Sedimentary rocks occupy an intermediate position towards the more acidic end of the scale as there is more rhyolitic material erupted than basaltic. Selenium is somewhat of an exception as it is not readily incorporated into minerals as they crystallise from melts.

Thus on the basis of geology we would expect trace element deficiencies to occur mainly in areas of acidic rocks, with decreasing deficiency as the rocks become more basic, with sedimentary rocks occupying an intermediate position (Hodder, 1983). Of course many factors will modify these basic geological differences in the transfer of trace elements from rock to soil to plants to the grazing animals, but they provide a good basis for understanding the occurrence of trace element deficiencies in animals.

COBALT

Cobalt deficiency was first documented in New Zealand in 1893 as a wasting disease of cattle and sheep grazing the pumice soils of the North Island. Later it was found that a similar disease occurred on the granite soils of the Nelson district, soils from greywacke loess in the Morton Mains district of Southland, and leached volcanic soils on the Mairoa plateau. (For an excellent account of the history of cobalt deficiency in New Zealand see Andrews 1970). The total area of definitely cobalt deficient farmland is estimated to be about 0.5 million ha. Areas of suspected latent or incipent cobalt deficiency total a further 2 million ha. Known and suspected cobalt deficient soil types have been documented by Andrews (1961, 1971). Appendix 1 summarises the associations between cobalt deficiency disease in animals and the type of soil classified according to the major soil groups and parent rocks or areas.

The deficiencies occurring on the pumice soils and soils from granite can be ascribed to the low cobalt content of the rhyolitic or acidic parent material (inherent deficiencies). Deficiencies on the more leached soils from Mairoa ash, and on podzolised soils, can be explained as due to loss of cobalt from the upper part of the soil by leaching, or podzolisation (acquired deficiencies). The occurrence of milder or marginal deficiency on such soils as those from greywacke alluvium in the South Island and lower North Island could be partly ascribed to the lowish cobalt content of the sedimentary rocks, but other factors are, no doubt, important in determining the occurrence of deficiency in these areas.

Newly diagnosed areas of deficiency are those on certain other areas of moderately leached soils from Mairoa ash, pumiceous alluvium of the Waikato basin, Whangamata pumice lapilli, and moderately podzolised soils from dacite and rhyolite on the Coromandel peninsula. The occurrence of deficiencies in these areas is consistent with geological and soil characteristics.

The lack of deficiency on the recent soils from volcanic ash which overlay in parts of the deficient pumice soils, and on the younger brown granular soils and red brown loams is related to the andesitic or basaltic nature of the parent rocks.

Severe cobalt deficiency is now rarely, if ever, seen due to the effectiveness of regular cobalt topdressing instituted many years ago in 'bush sickness' areas. In fact the pumice soils of the volcanic plateau now have a more adequate cobalt status than many other areas and research is now aimed at defining minimum levels of cobalt application needed to maintain adequate cobalt levels (Sherrell *et al.*, 1981). Today cobalt deficiency is more often found in marginal areas where it may only occur in some seasons and not others. For these areas the soil map and soil classification still provides a guide as to the likelihood of possible deficiencies. However more detailed investigations are needed to establish the extent and location of any deficiencies.

COPPER

Copper deficiency was first recognised in New Zealand as a scouring disease of cattle grazing reclaimed peat lands and the cause of ataxia ('swayback') in lambs (Cunningham, 1946). It was soon found that copper deficiencies occurred in other areas of the country, notably certain pumice soils, rendzinas, saline soils, some recent soils and some steepland soils. Deficiencies were often complicated or induced by an excess of molybdenum in the pasture (Cunningham, 1950). Later it was found that other components of diet, notably sulphate, iron, and zinc, influenced copper uptake by animals and thus the occurrence of copper deficiency. The copper and molybdenum content of rocks follows the expected pattern of being high in basic rocks and low in acidic rocks. However, Wells (1957) found only a low correlation between the copper content of soils and that in sweet vernal and no correlation between the molybdenum content of the soil and that in sweet vernal (Wells, 1956). (A correlation was found between molybdate retention and the molybdenum content of sweet vernal).

From the foregoing it will be apparent that there is no simple geological basis for the occurrence of copper deficiencies in animals. However classification of deficiencies by soil types is still useful. Cunningham *et al.* (1956) used soil types as the basis for determining the areas of New Zealand where copper deficiency may occur, from the copper and molybdenum content of pasture samples. He found that relatively small areas in New Zealand had pastures low in copper (<3 ppm) but large areas, about 2 million ha, mainly in the North Island, produce pastures with high (>3 ppm) amounts of molybdenum. Samples collected from different areas of the same soil type showed uniformity in molybdenum content and major differences occurred between soil types.

Soils on which copper deficiency diseases in animals occurred generally had elevated pasture molybdenum levels. Arranging soils into suites (i.e., soils of one kind of parent rock placed in a sequence of soil development) is a useful means of classification and engenders an understanding of the reasons for their nutrient status (Taylor *et al.*, 1956) particularly in Northland (Ensor, 1956).

Molybdate topdressing and liming is believed to have had a major influence on the occurrence of copper deficiency disease in animals. Cunningham and Hogan (1956) examined the influence of molybdate topdressing on pasture molybdenum content. They found that the effect differed markedly with soil type. The soil types which produced excessively high molybdenum levels after topdressing (>3 ppm after 3 months) have been summarised and mapped by Cunningham (1960), as well as those that produce naturally high molybdenum or low copper levels.

The occurrence of reported copper deficiency in animals classified according to soil groups is in Appendix 2.

SELENIUM

Selenium was discovered to be an essential trace element in comparatively recent times (1957) and was soon shown by workers in Oregon and New Zealand (Hartley and Grant 1961) to prevent 'white muscle disease' in new-born lambs. It was soon found that selenium deficiency was also a cause of a barren ewe problem often associated with white muscle disease occurrences and a cause of illthrift in young sheep and cattle. Selenium responsive illthrift was found to be the most widespread and economically important disease (Andrews *et al.*, 1968). The total area where selenium responsive diseases in grazing animals occur is estimated to be 4 to 5 million hectares (Watkinson, 1981).

Selenium shows very definite rock-soil-plant-animal relationships in pastoral grazing systems in New Zealand. Low amounts of selenium are found in rhyolitic rocks and granites, high amounts in andesites and basalts and low-intermediate amounts in greywacke-sedimentary rocks (Wells, 1967a). These broad differences are carried through with some modification to the soil (Wells 1967b), to the plants, through to blood levels in grazing animals (Fraser and Kirk, 1981) and the occurrence of selenium responsive diseases (Robertson and During, 1961, Hartley and Grant 1961; Andrews *et al.*, 1968). Important soil factors modifying this broad generalisation are:

1. The degree of weathering; there is an increase in soil selenium content with weathering in the sequence from brown grey earths to yellow grey earths to yellow brown earths (Watkinson, 1962; 1981), and also in volcanic soils as volcanic glass weathers to allophane. (Hodder and Watkinson, 1976).

2. Soil drainage; there is a decrease in animal blood selenium levels with increasingly poor drainage (Fraser and Kirk, 1981). This is mainly due to reducing conditions in soils of high water table decreasing the availability of selenium to plants (Watkinson, 1962).

3. Podzolisation; the formation of podzols under the influence of mor forming trees, particularly kauri, results in lower soil selenium levels (Watkinson, 1981) and blood selenium levels in cattle (Fraser and Kirk, 1981).

The relationships between selenium responsive conditions in cattle and sheep and soil groups is summarised in Appendix 3.

CONCLUSIONS

Relationships between geology and soils and the trace elements status of animals are well defined for cobalt and selenium, but rather poorly defined for copper. Nevertheless for all 3 elements, classification of trace element data by soil type has proved very useful.

The soil type has provided a basis for delineating areas where trace element deficiencies are likely, where they are unlikely and where further investigations are needed. In the past this has enabled the rapid and systematic application of treatment and control measures. Furthermore, arranging soils in sequences of development (suites) engenders an understanding of the reasons for their nutrient status.

However, soil type classification cannot be used to reach a definitive diagnosis as to whether trace elements are needed on a particular farm. To do this we must follow the well known soil scientist Norman Taylor (1952) when he so rightly said 'If we wish for the truth we must ask it of the animal'.

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APPENDIX 1 Cobalt status of New Zealand soil groups.

Soil group	Parent material (or zone)	Av. Co. Content mg/kg DMB			Deficiency disease in animals	Reference
		Soils[1]	Pasture[2]	Sweet[3] vernal		
Brown-grey earth					None recorded.	
Yellow-grey earth		6.4	–	0.07	Lamb responses on stony silt loams from greywacke in Canterbury and Otapiri soils (Southland).	1,2 5
Lowland Yellow-brown earths	granite	0.4			Severe (bush sickness) on granite soils in Nelson.	3
	tuffaceous greywacke	4.7			Moderate at Morton Mains (Southland) (Morton Mains disease).	4,5
	dacite and rhyolite				Lamb weight gain responses recorded at Whitianga (Coromandel).	6
Podzols	Northland	0.4	0.06		Deficiency likely on more podzolised soils and podzols.	7
	Westland	0.5			Lamb response on Utopia soils.	8
Recent	Volcanic ash	5.0	0.07	0.06	None recorded.	9
Yellow-brown pumice soils	Taupo ash	1.3	0.03		Severe (bush sickness) on most	
	Kaharoa ash			0.03	Taupo and Kaharoa pumice	10
	Gisborne ash				Moderate deficiency on soils from Gisborne ash.	11
	Whakatane ash				Marginally deficient (Andrews, reference 34). No responses in Robertson and During's survey (reference 37).	12
Yellow-brown loams	Mairoa ash	4.9[4]	0.03[4]		Severe to moderate on very strongly leached soils on Mairoa plateau (Mairoa dopiness).	13
				0.04	Lamb weight gain responses on other moderately leached soils.	14
	Maihihi ash				Classed by Andrews (reference 34) as marginally deficient. Lamb weight gain responses.	6
	Waihi ash				Waihi sandy loam marginally deficient (Andrews, reference 34) Pastures show low Co levels.	15
	Egmont ashes	11.6			None recorded.	
	Whangamata lapilli				Moderate in lambs.	16
	Pumice alluvium				Considered to be potentially deficient for	11
	(Waikato basin)				sheep in parts. Lamb weight gain response on one site.	14
	Volcanic ash & greywacke alluvium (Hawkes Bay, Wairarapa, Hutt Valley)				Moderate to marginal particularly on the more stony soils.	32

APPENDIX 1 Cobalt status of New Zealand soil groups—*continued*

Soil group	Parent material (or zone)	Av. Co. Content mg/kg DMB			Deficiency disease in animals	Reference
		Soils[1]	Pasture[2]	Sweet[3] vernal		
Brown granular soils	Andesite & andesitic basalt (Northland)			0.05	The more mature soils moderately to marginally deficient (Andrews, reference 34).	7
	(Southland)				Drummond soils marginally deficient (Andrews, reference 34).	
Red and brown loams	Basalt	8.5		0.08	The more mature soils moderately deficient (Andrews, reference 34).	11,7,9
Recent from alluvium and loess	Granite	0.4			Severe to marginal on granite alluvium in Nelson province.	3
	Greywacke	7.6[5]		0.15	Lamb weight responses on Eyre soils.	1
Yellow-brown sands				0.08	Coastal sand from Patea to Paekakariki marginally deficient. No trial responses obtained on imperfectly drained members. Otatara sand near Invercargill moderately deficient (Andrews, reference 34).	37
Gley soils					None known.	
Organic soils				0.04	None known.	
Rendzina soils				0.10	None known.	
Steepland soils					Deficiencies on steepland soils related to yellow brown pumice soils and granite, largely unsuitable for farming.	

1 Reference 35.
2 Reference 11.
3 Reference 36.
4 From Mairoa plateau only.
5 From Ashburton County.

APPENDIX 3 Selenium status of New Zealand soil groups.

Soil group	Av. Se Content Soil[1] mg/kg	Cattle[2] blood μg/l	Deficiency disease in animals	Reference
Brown grey earths	0.25	–	Responses in lambs.	23
Yellow grey earths	0.27[3]	–	Responses in lambs in South Is.	23
Yellow-brown earths	0.55[3]	29[5]	Responses on some Southern YBE and high country YBE in the S.I. None in N.I.	23
Podzols	0.39	14[5]	Positive (non sig.) responses in lambs and calves in S.I. Response suspected in Northland (low soil and blood levels).	8, 24
Recent from volcanic ash	0.44	170[4]	Uncertain; not expected on Ngauruhoe or Rangitoto ash, may occur on Tarawera basalt, likely on Rotomahana mud. Lamb responses reported on Ngauruhoe soils.	25,26, 27
Yellow-brown pumice soils	0.30	10	Lamb responses on coarse soils of central volcanic region.	23,27
Yellow-brown loams	2.1	34	Deficiency uncommon. Marginal blood Se levels on pumice alluvium of Waikato basin. Small weight gain response in sheep on intergrade to YBE in Hutt Valley.	26, 28,29
Brown granular soils	2.3		None known.	
		42		
Red and brown loams	2.5		None known.	
Recent soils from alluvium	0.26[3]	–	Lamb responses on many recent soils on eastern side of S.I. Weight responses in calves but not lambs on the West Coast. Low blood Se reported in Manawatu.	23, 8, 17
Yellow-brown sands	–	–	Responses on sands in the Manawatu.	23
Gley soils	1.0	19	Marginal Se status in Waikato district.	30
Organic soils	0.15	17	Responses in lambs and calves.	30,31
Rendzina soils	1.2	–	None known.	
Saline soils	0.3	–	None known.	
Steepland soils (N.I.)	1.1	51	None known.	

1 From reference 33 averaged over soil types.
2 From reference 26.
3 Soil types containing andesitic ash excluded.
4 Rangitoto ash only.
5 Northland only.

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