THESIS.

PINE DISEASE IN SHEEP ON THE CHEVIOTS.

BY

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C O N T E N T S.

I L L U S T R A T I O N S.

DIAGRAMS.

PHOTOGRAPHS.

PINE DISEASE IN SHEEP ON THE CHEVIOTS.

1. THE NATURE OF THE INVESTIGATION.

In certain parts of the Cheviot Hills on both the Scottish and English sides of the Border, there exists a disease among sheep, known as Pine, or Pining, which is a source of considerable loss to flockmasters. A large area of hill land in Roxburghshire is affected with the disease, and also a considerable acreage of arable land. As a result of a survey of the problem, it has been found that the chief area involved amounts approximately to 80 square miles, while the sheep stock totals 40,000 sheep.

While the disease is not confined to any one geological formation, it has by far the greatest incidence on soils arising from certain of the Andesite rocks. This applies to the Scottish side of the Cheviots. The occurrence of Pining on the English side lies outwith the scope of this enquiry.

On the Scottish Borders there are two main formations which go to form the Cheviot Hills. In the eastern portion there occurs a wide belt of Andesite rocks of Old Red Sandstone Age, stretching approximately from Yetholm to Carter Bar and forming what is generally called the East Borders. To the west of Carter Bar the rocks chiefly belong to the Carboniferous formation. Pining is found in its most acute and widespread form in the East Borders

on the Andesite, including part of the Parishes of Crailing, Eckford, Hounam, Jedburgh, Morebattle, Oxnam, and Yetholm, all in Roxburghshire. The investigations which form the subject of this thesis have principally been conducted in this region.

The Cheviot Hills and the numerous valleys and tracts of pasture in the vicinity appear to be well adapted for sheep. The hills rise to a moderate height, seldom exceeding 1600 feet, and are usually covered with green grass to their summits. This grass forms a dense turf of fine-leaved herbage covering wide stretches on every hill farm, and giving the type of herbage on which sheep in the ordinary way are generally considered to do well. The climate of the area is amongst the driest and most favourable for the sheep enterprise in Scotland. Nevertheless, a very large tract of this land is so unhealthy for sheep that, according to the testimony of farmers, the greater proportion of hill stocks would die out within two years if allowed to remain on the same ground without a change of pasturage.

The disease has a comparatively sudden onset. Sheep which have apparently been in good health may suddenly receive a check and within a few days exhibit various signs of debility and malnutrition. There may be an abundance of fresh leafy herbage brought on by genial weather in early summer; nevertheless, affected animals ultimately become as lean

as skeletons in this abundant pasturage, and unless removed from the ground, they get so weak that they are ultimately unable to rise. The only method in the past of obviating the trouble has been to arrange regular changing of the flock once or twice a year which acts as a preventive. This system involves much expense and inconvenience and does not always prove effective. Owing to the extensive area in which it is prevalent and the large number of sheep involved, the disease of Pine constitutes a problem of the first importance to sheep farmers in affected districts.

Before the experiments detailed in this thesis were begun, the cause of the disease had never been definitely established. Farmers believed it had some connection with the soil or herbage, but no organised investigation had been conducted to throw light on the problem. No method of combating the trouble had been evolved apart from the time-honoured system of changing the flock as a policy of prevention, or of sending away animals for a change once they had become affected. As a result of the present researches, however, the actual cause of the disease has been elucidated, and the problems of prevention and cure in actual practice have to a large extent been solved.

In 1933, a request for assistance was received by the writer from a sheep-farmer in the affected

area, and an experiment was carried out on his farm. Enquiries were made among neighbouring farmers and a Memorandum on the subject was prepared by the writer giving a preliminary survey of the problem. An article by MacGowan and Smith which had appeared in the Scottish Journal of Agriculture for July 1922 proved of value. Following upon this Memorandum, the Authorities of the Edinburgh and East of Scotland College of Agriculture resolved in 1934 that an enquiry be instituted into the whole question, and the Animal Diseases Research Association, Edinburgh, kindly collaborated in certain aspects of the work during 1934 and 1935.

The writer has been actively engaged in investigating the disease since 1933, and the whole of the experiments in the Cheviot Area described in this thesis were carried out by him. In addition, an examination has been made by him of the Geology and Soils of the region, and also of certain features of the Botany of hill pastures. A survey of the district has been made as a result of visits to all farms in the East Borders, and a map has been prepared outlining the affected area. The results of this work have been embodied in the thesis.

The writer wishes to acknowledge the kind help received from Professor Shearer in giving facilities for the work, and also to Dr. A. Lauder for his advice and assistance. Special

thanks are due to the many farmers and shepherds who carried out the experiments and particularly to Mr. Andrew Taylor, Middlesknowes, Jedburgh.

2. HISTORICAL REFERENCES TO PINE.

The disease has been present in the Cheviot area for generations and has been described by various writers in agricultural journals during the past hundred years or so. Earlier than this there are no records of its occurrence in the Borders. No mention of it is to be found in the Old Statistical Account of Scotland (1) in any of its volumes relating to the Borders. These were published in the years 1791-98 and describe many of the common diseases of sheep and cattle which prevailed in Border Parishes at that time. As the disease occurs nowadays on a widespread scale in seven Parishes in Roxburghshire and on many farms in neighbouring counties, it could hardly have escaped mention if it were actually prevalent to any extent at that period. This view is supported by the fact that no allusion to it is revealed in the book describing the Agriculture of Roxburghshire and Selkirkshire written by R. Douglas in 1798 (2), or in the Account of the Agriculture of Peeblesshire, published in 1802 (3).

It is not mentioned as occurring in the Borders in "The Shepherds' Guide" published by James Hogg, the Ettrick Shepherd, in 1807 (4), though Hogg

records its existence elsewhere. This is of special interest because James Hogg was a shepherd at Blackhouse in Selkirkshire from 1790 to 1800. The Craighope hirsel on Blackhouse is, at the present time, much affected with Pining, the writer having supervised the treatment there of Pining sheep in 1936. There could have been no Pine in Hogg's day, otherwise he would have been only too familiar with it at the time he wrote his book.

In 1822, Napier issued an exhaustive treatise on Border Sheep farming, (5) but here again there is nothing to indicate the prevalence of Pine. Were it indeed present to any extent in the Borders it could hardly have been omitted by one or other of these writers.

Apart from the Borders, the earliest reference to Pine in any part of Scotland that the writer has been able to discover is contained in "The Shepherds' Guide" 1807 (4) already referred to. In this book Hogg states in regard to the condition that "it is confined mostly to districts in the West of Scotland, where the land is very coarse. It is distinguished in different Shires by the three following names, Pining, Daising, and Vinkish." In the same article he mentions that it was present in a severe form on some farms in Galloway. At that time apparently there was no appearance of the disease in the Cheviots, otherwise it is likely that

Hogg would have known of it, as his writings show that he was a particularly keen student of the various maladies of sheep and their distribution in Scotland. Information relating to the farming experiences of Hogg, and the districts in which he resided, have kindly been supplied to the writer by Mr. W. Laidlaw, Syart, Yarrow, Selkirk, the descendant of a relative of James Hogg, and possessed of very full details of his life.

The first allusion to Pine in the Borders is contained in an article by Hogg in the "Quarterly Journal of Agriculture" Vol. 11, 1831 (6). He writes "The most destructive and ruinous disease among sheep at this time over all the south of Scotland is that called Pining. Well may I describe it, for in the course of the last nine years I have lost upwards of 900 sheep by its ravages. It is quite a new disease on the Borders for I was twenty years a shepherd and never saw an instance that I can remember of with certainty, nor did I ever hear its name, save from Galloway where it is called "The Vinquish" and where it has been prevalent for ages. It was likewise known long ago in some of the districts of the middle Highlands". The Editor of the Journal, Professor David Low, in an article in the same issue (7) states "The principal districts in which the disease is found to prevail are the green pastures of the Cheviot

mountains, the chain of hills running through the south-west parts of Roxburghshire, the pastoral districts of Selkirk and Peebles Shires, and some other districts of Scotland, as Galloway." The above quotations and other interesting details from Hogg's article are embodied in an article by MacGowan and Smith (8) referred to earlier.

It may be concluded from these extracts that Pining was known in a severe form in the Borders in the early part of the nineteenth century. If present before that time, it was either of too mild a character to be recorded by contemporary writers, or was not recognised by farmers as a definite disease in the classification of maladies of stock then current.

3. CHANGES IN SHEEP FARMING WHICH GAVE RISE TO PINING IN THE NINETEENTH CENTURY.

It may be that the appearance of Pining on a considerable scale in the Borders in the nineteenth century was partly brought about by changes in sheep farming which were then in progress. The effect of such changes carried out perhaps some years before might conceivably produce effects upon the stock which would render them more susceptible to this particular disease. As will be shown later in this thesis, the cause of Pining has been established as a form of mineral deficiency and its occurrence is intimately connected with many aspects of sheep husbandry. The question may be asked - Were there alterations in methods of management of sheep stocks, or of the grazing lands, or changes in the breeding of the sheep themselves, which would account for its appearance? It may be of interest to consider some of the developments which are known to have taken place at that period and their probable bearing on this question.

About the time of the Napoleonic Wars there was a period of unexampled prosperity in farming. Imports of commodities were much restricted, and the prices of produce of every description were consequently at unusually high levels. Wool shared in the upward trend owing to demand from the textile

industry then rapidly developing. Mr. John Wilson, Edington Mains, Berwickshire, a contributor to a Report issued by the Highland and Agricultural Society of Scotland (9) states "The agricultural progress of Scotland during these twenty years (1795-1814) is probably unparalleled in the history of any other country. As one proof of this, the rental of her land, which in 1795 amounted to two millions of pounds sterling, had in 1815 risen to five and a quarter millions - that is, had well-nigh trebled in twenty years".

This was the period during which an extention in sheep farming took place all over Scotland and in which Cheviot sheep from the Borders were in demand for stocking large tracts in the Northern Highlands through the pioneer work of Sir John Sinclair, the founder of the British Wool Society. Sir John first introduced Cheviot sheep into the North in 1792. McCallum (10) quotes from the report of Andrew Kerr, who surveyed the North of Scotland on behalf of that Society that "a fine woolled sheep called the "Long Hill Sheep" of the East Border" might thrive in parts of that region, a report which was acted upon most diligently.

Increased Stocking with Sheep.

Under the prevailing conditions of the period it is reasonable to suppose that sheep stocks in the

Borders would tend to increase, as there would be every inducement to obtain the maximum benefit from the high prices. As the natural result of heavier stocking of hill farms is to increase the susceptibility to disease, it is possible that this may have been a contributory factor to the increased incidence of Pining. Most farmers in the area today agree that Pining would be reduced were the grazings lighter stocked. It is true that certain farmers take the opposite view, as MacGowan and Smith point out, the idea being that the sheep spread themselves better over the grazing and so obtain greater benefit from the varying soil and herbage. While increased stocking might be beneficial at the outset, there is little doubt that it would be detrimental in the long run. Farmers in those days had scanty facilities for providing supplementary feeding in winter for increased stocks in times of stress. Writers of the period invariably refer to the difficulties of wintering, and it is well-known that stock in a debilitated condition in spring are more disposed to exhibit symptoms of Pining than those which have been well wintered.

Grazing Mixed Ages of Sheep.

That there was some change responsible for the onset of the malady must have been present in the mind of the Editor of the Quarterly Journal of

Agriculture, 1831 (7) already referred to. He states that Pining was unknown under the old system of pasturing the milk ewes by themselves, separate from eild sheep such as hoggs and wethers. The old system is referred to by Douglas (2) as follows, "though flocks may sometimes range promiscuously in winter, yet in early spring they are separated into different parcels (provincially hirsels) of hoggs, gimmers, wethers, and ewes, each of which, under a different shepherd, is kept on a different part of the farm". Cully (11) also refers to this method of management. When, however, the practice was adopted of allowing all ages of sheep to graze together indiscriminately, the Editor asserts that Pining made its appearance.

There is reliable evidence to-day to show that such a change would indeed be conducive to Pining on East Border farms. It is found, for example, on most of these farms that hoggs do not thrive properly if occupying the same ground as ewes. In fact, on several farms it is impossible to rear a suitable class of hoggs and keep them free of Pine unless they have their own grazing grounds. The universal practice in the district at the present day is to run the sheep in separate ages. This is found essential for the health and well-doing of the flock. It is reasonable to conclude, therefore, that the indiscriminate grazing referred to would

tend to favour the disease, particularly in the younger ages of sheep.

The same writer refers to another point of difference in the systems under discussion. It was customary under the old practice to wean the lambs in July and August and to milk the ewes for eight or ten weeks thereafter. When this was superseded by the later custom of indiscriminate grazing, the lambs remained unweaned until they weaned themselves which was generally not until December. To the modern view both these practices seem unduly exacting on hill ewes. Both would be likely to bring about Pine on a wholesale scale in the affected area at the present day. The fact that under the hand-milking system, however, the ewes would be driven over the ground to a greater extent would be to the advantage of that system. It is regarded as a fundamental principle on pining farms that to keep the sheep moving helps to promote bodily functions, and that to leave the sheep in a more or less undisturbed state is likely to favour Pining.

Enclosure of Farms.

A development of importance which went on at that time in the East Borders was the enclosure of hill farms. Many of these were ring-fenced by means of stone dykes, thus restricting the grazing of sheep within more definite limits. The sheep before this

period would have access to a wider range of ground and, in the opinion of farmers who have been consulted on the subject, the enclosing process would, in the case of certain farms, be detrimental to the stock.

On the other hand, there are farms which were never fenced until the coming of wire fencing towards the middle of the nineteenth century and which are known to have been affected with Pine long before that. Enclosure in such instances made little difference because the adjoining ground was Pining in any case.

Light Stocking with Cattle.

Whether there were ever large stocks of cattle grazing on the Cheviot Hills is difficult to ascertain. We know that other hill districts in Scotland carried large numbers of cattle before the great boom in sheep. Probably this did not apply to the same extent to the Cheviots, and it is not claimed that a marked change necessarily occurred in this direction there. It is certain, however, that from the close of the eighteenth century onwards the area was almost entirely given over to sheep and that in the East Borders the hill farms were more heavily stocked with sheep than probably any other district in Scotland.

Douglas (2) in describing the rate of stock-

ing about the year 1798 says, "It seems to be admitted that an acre will nearly maintain a sheep to the south of Jedwater, but that to the north of it about 1½ of an acre will be requisite, and that in a great part of Liddesdale a sheep will eat almost the whole produce of two acres". The area south of Jedwater exactly comprises the East Borders. It is evident, therefore, that in those days the rate of stocking was unusually high. It may be mentioned that at the present time it is customary for farmers in the district to reckon on a similar carrying capacity, namely, one sheep per acre. In practice, however, the numbers usually fall slightly below this figure as the sheep are found to do better when not so thick on the ground.

From Sir John Sinclair we get reliable information to show that the stocking at that time was almost entirely sheep. Writing in 1814, Sir John (12) states :- "At the present time there are few cattle kept on the Cheviot Hills, and with the exception of a very small number of cows and horses for the use of the farmers and their herds, and a few patches of arable land on some farms, the whole district is occupied by sheep". This definitely shows the preponderance of sheep, which, as we have previously learnt, were present in very large numbers. Whether this was a new phase cannot well be ascertained without special enquiry.

The absence of a reasonable stock of cattle is well-known at the present day to favour pining in some districts. The sheep are more inclined to concentrate on the shallower ground where the herbage is finer and shorter, but which more readily gives rise to the disease, as will be referred to later. The presence of cattle, on the other hand, helps to keep down the rougher portions and to make a wider range of ground available to sheep.

Changes in the Type of Sheep.

Not the least important development of the period was the effort made to improve the type of sheep in hill districts. The eighteenth century had seen revolutionary changes in arable farming by the introduction of the turnip crop, improved methods of soil cultivation, and the feeding of farm stock. Farmers and landowners were everywhere exploring new methods in the management and utilisation of the land. This condition of affairs spread to hill farming. The native breeds or races of sheep which were in occupation were no longer regarded as fulfilling the demands of the time, and large-scale experiments were begun on this subject in the Borders and elsewhere.

From time immemorial a race of sheep had been in existence on the Cheviot Hills, though what their origin was is difficult to ascertain. Watson and More (13) state "The Cheviot is regarded as derived from

the ancient Celtic tan-faced breed, and would thus be related to the old soft-wooled sheep of the Western Highlands and Hebrides. It has existed on the hills of Southern Scotland from very early times, though formerly the breed was much smaller and probably finer-wooled than now".

As to the name of this breed, in the first volume of the Cheviot Flock Book (14) it is stated that they "are mentioned in a writing as far back as 1470 as the sheep of the Cheviot Hills called the "long" sheep". This was evidently the term applied to them in contrast to the Blackface type of sheep which was known as the "short" sheep. All writers on the subject state that a distinctive race of "long" sheep inhabited the district around "The Cheviot" lying just beyond the Scottish Border. This is the region which nowadays is most affected with Pining. Other parts of the Borders were mainly devoted to the "short" sheep, these being better adapted to rougher grazings with plenty of heather.

The term "Cheviot" was not given to the breed until the late eighteenth century, when it was first used by Sir John Sinclair.

As to the characteristics or the appearance of this race of sheep before improvements were introduced, there is no reliable record. That they were well adapted to the district is beyond doubt, otherwise they would not have maintained their distinctive

hold. Barber (15) refers to old records and quotes as follows, "large tracts of the Cheviot Hills are described as covered with a small but very hardy race of sheep". Having been bred for generations without undue selection for economic purposes as we know it to-day, such a race would be well suited to the area by natural vigour and hardihood. They were a comparatively small, light-framed breed and made no exacting demands upon subsistence. It is also conceivable that they were to a large extent resistant to Pining. Native races of sheep are well-known to withstand rigours of climate and poverty of fare which improved breeds are unable to tolerate. That they would thrive on the sweet grassy pastures of the East Borders where conditions are extremely favourable and where they would only be called upon to endure a slight nutritional defect is highly probable.

Native Sheep on Pining Land.

In support of the view that the original sheep of the Borders at some former period were more or less immune to Pining, an example may be quoted from a district in Scotland where, at the present day, sheep are bred and reared on Pining land without succumbing to the disease, although there are occasional deaths from this cause. These are the native sheep of North Ronaldshay in the Orkney

Islands. The writer has visited this Island on several occasions. Approximately 2,000 native sheep are kept on the beach and foreshore of the Island, the whole of the Island being walled round for eleven miles to keep them off the farm lands. They subsist entirely on seaweed and the scanty herbage growing on the links. Sheep other than ewes are never allowed off the beaches. The ewes gain access to grass on the Island only when rearing lambs. The links are largely composed of shell-sand, samples of the sand taken by the writer from three deposits showing an average content of 74% of Carbonate of Lime. This sand heavily impregnates all the land in the vicinity.

In all other districts in Orkney where stock of present-day breeds are reared on land with an unduly high proportion of shell-sand, as in parts of Sanday, Westray, and Burray, Pining is prevalent both in cattle and sheep. Similar soil conditions prevail on part of the Island of Tiree (16) where Pining is a serious malady. Attempts to improve the North Ronaldshay sheep by the introduction of tups of modern breeds have always failed, as the progeny are lacking in hardiness and stamina.

This is an extreme example of the adaptibility of a present-day native race of sheep in Scotland. That the old-time sheep of the Cheviot Hills could withstand Pining under infinitely better conditions may be accepted as almost certain. So long as the

sheep were bred without undue interference with the existing type, Pining was little known. When, however, "improved" breeds of lowland origin were introduced among them, their natural resistance to this malady would gradually be suppressed. That this infusion of lowland blood did take place among Cheviot sheep is well established from the recorded history of the breed. This aspect of the subject may now be considered.

Changes in Breed Described.

In the book written by Douglas in 1798 already mentioned (2), the author describes the importation of a consignment of sheep into the Cheviot country from Lincolnshire. He writes "three farmers, viz:- Mr. John Edmistoun, late of Mindrum, and Mr. James Robson, then at Philhope, both in Northumberland, and Mr. Charles Ker, then at Riccaltoun in this County, went to Lincolnshire about 40 years ago, before the breed there had degenerated, and purchased 14 rams, picking out of three score in the possession of one man". He goes on to say that Mr. Robson brought their progeny into Roxburghshire in 1760, and that, many years after, Mr. Robson was of the opinion that the good effects of this infusion of blood were still to be seen in his flocks. These facts are also alluded to by a recent writer on the Cheviot breed, Robson (17). It is evident, there-

fore, that the stock on this hill farm were partly built up from the produce of these rams and that the rams were not merely used to produce crosses for sale purposes. Mr. Robson came to Belford, Roxburghshire, in 1760 and later went to Chatto. These farms are both situated in the East Borders.

Douglas continues "Since that time, by various changes of rams, some of which have a proportion of the Dishley breed, and by a judicious selection of shapely ewes for breeding, several neighbouring flocks may vie with those of Mr. Robson." As the farms in the vicinity of Belford and Chatto are nearly all hill farms, it may be assumed that the practices referred to were mainly carried out upon hill sheep. Improved strains were evidently established and these were available as a reservoir for other flocks in the area.

Douglas further states "There are 5 or 6 small flocks of the Dishley breed, kept by gentlemen in rich inclosures, and by one or two farmers in the arable district ..... Their bones are small and neat, their backs broad and flat, and their bodies round like a barrel ..... There is at present, an appearance of their becoming more general in the lower parts of the County, and of further experiments being tried by crossing Cheviot ewes, in hilly pastures, with rams having more or less of their blood". Here also there is some

evidence of a certain amount of the Dishley or Leicester blood being diffused among hill breeding stocks.

Reference is also made by Douglas to the introduction of a number of Herefordshire and Southdown sheep. In commenting on the results, he says "The Herefordshire, from their apparent delicacy, and the lightness of their fleeces, will not probably become favourites, notwithstanding the fineness of their wool. The Southdown, on the contrary, whose wool is little inferior, and who are lively, active, and hardy, bid fair to answer on high grounds, and to improve the wool of the Cheviot sheep, without materially lessening or hurting their shapes". Douglas states that two of the farms to which these sheep were introduced were Plenderleith and Chatto. It may be mentioned here that both of these farms are affected with Pine at the present day. They are primarily hill farms with a limited amount of arable land. Whether these experiments were restricted to sheep on the enclosed portions of the farms is not clear, but it would appear that the actual hill sheep were involved.

That other changes in the breeding of sheep were also in vogue at the time in Roxburghshire is apparent from the testimony of Douglas who gives an account of facts which he states came within his own observation. He writes "In many farms, an entire

change has been effected from the black-faced to the white-faced sheep, by using Cheviot rams for a succession of years".

Enough has been written to show that far-reaching changes were in operation among hill sheep at the period, and that the existing race of sheep on the Cheviot Hills was gradually being altered in size, shape, type of wool, and other characters. That there was some inevitable loss in constitution accompanying these changes, there can be little doubt. Wallace, writing of the Cheviot breed, (18) has summed up the situation in the following sentence:- "The same course of action as that taken in the establishment of other successful sheep breeding industries, seems to have been quite unconsciously followed; an extremely hardy but comparatively worthless breed, capable of adjusting itself to adverse circumstances in its surroundings, was gradually improved by the introduction of finer bred but less hardy kinds of sheep".

It is not suggested that before the breed of sheep was modified there was little or no disease among sheep. It is in fact on record that many of the common diseases of the present day were prevalent before there was any notable change in this direction. Such maladies as Braxy, Louping Ill, Liver Rot and Sturdy are described by various writers in the Old Statistical Account as long established aliments

affecting hill flocks in the Borders. It is contended, rather, that an increased disposition to Pining followed in the wake of improved breeding in the East Borders.

Pining in the Hogg Country.

The country in which James Hogg herded sheep and latterly became a sheep-farmer was not the East Borders, but certain districts in Selkirkshire and Peeblesshire, and parts of Dumfrieshire. His own experiences with Pine, therefore, refer to those counties only. Here also widespread changes had occurred, similar to those enumerated in the Cheviot region.

One of the most notable developments in Selkirkshire was the gradual change over from Blackface or "short" sheep to Cheviots, chiefly brought about by the use of Cheviot rams. Douglas in 1798 states "this County (Selkirkshire) is wholly stocked with white-faced sheep, except a tract towards the sources of Ettrick and Yarrow-waters ..... The change, from the black-faced kind, was effected in most places by using Cheviot tups, for a succession of years, till all traces of the coarse wool, short bodies, black faces and legs, disappeared."

Wallace (18) in writing on Cheviot sheep states "Lord Napier testified before the House of Lords that the Blackface sheep had been driven out

of the whole of Selkirkshire, including Ettrick Forest, and substituted by the Cheviots".

Most of the available evidence goes to show that this change in breed which was carried out in order to obtain a more valuable quality of wool and an increased weight of carcase was accompanied by some sacrifice in hardiness of the original stock. Douglas indeed disputes this, but other writers comment upon it. William Hogg, an elder brother of James Hogg, who was shepherd at Stobo in Peeblesshire (19), and contributed several articles to the Quarterly Journal of Agriculture, wrote in 1828:-

"About half a century ago, the hills in the South of Scotland were stocked with a hardy race of sheep, every way adapted for mountainous and rugged pastures. Health, animation, and vigour, with a taste truly adapted for coarse, mossy herbage distinguished this ancient race, and these were peculiarities absolutely necessary in a breed which had to struggle through a hard and prolonged winter, in a rude and boisterous clime. But by and by the fleece became an object of attention, and unluckily it was cultivated as a distinct concern, without a proper regard being paid to the more important excellencies of muscular strength and vigour, which the old breed possessed in an eminent degree.

To bring about this change in the coat of the old forest breed, Cheviot rams were brought from

the celebrated range of mountains known by the same denomination, and admitted to the hardy natives of the more elevated parts of the country. The independent habits of the mountain flock were lost, and a mongrel progeny of a clumsy figure occupied the lowest and warmest of the pastures".

In the article on Pining by James Hogg already mentioned (6), he writes "In 1823 I chanced to go to the hill one morning in June, not the least aware that the pining had set in, and found upwards of twenty scores far gone in it, and new ones getting affected every day". He goes on to say that he changed them on to new grass, but in spite of everything he lost fourteen score of them.

It is worth noting at this point that the farm which Hogg occupied at this date was Mount Benger in Yarrow (20), of which he had become tenant about the year 1820. It is recorded in Napier's "Store Farming" (5) that Benger Burn (Mount Benger) had a Cheviot stock at this time. This gives support to the view that Cheviot sheep of the period were liable to suffer a good deal from Pining.

As time went on, the tide once more turned in favour of the Blackface. Russel (21) writing of the Parish of Yarrow in 1845, says that the process of replacement had already begun, as Blackfaces "in stormy seasons are by far the surest stock". It is possible, therefore, that the change to a softer

class of sheep was partly responsible for Pine in Selkirkshire on the scale reported to be prevalent in Hogg's day.

SUMMARY.

The evidence goes to show that the breeds of sheep in the Borders were considerably modified during the course of the eighteenth and early nineteenth centuries. The process was a gradual one, occupying a long period of years, but it ultimately spread to most districts and had permanent effects upon the stock. In the East Borders an improved type of Cheviot gradually replaced the existing stocks, while in other parts of Roxburghshire and in Selkirkshire the old Blackface or Heath sheep was largely supplanted by the Cheviot. It was the old story of indigenous races being compelled to conform to more highly specialised types. As so often happens when fresh blood is introduced to grade up indigenous races, there was a break-down in the natural resistance of the animals to a malady to which they were formerly inured. These developments in breeding in the eighteenth century, taken in conjunction with other changes in sheep husbandry, ultimately led to a widespread disposition to pining on farms in the Borders.

4. PREVIOUS EXPERIMENTAL WORK ON PINE IN SCOTLAND.

The only record of controlled experiments on Pine in Scotland, prior to the investigations described in this Thesis, is an account of experiments made in Tiree in 1931 by the Animal Diseases Research Association in conjunction with the Rowett Research Institute (16). A summary of the results was later contributed by Greig (22) to the Scottish Journal of Agriculture. The type of Pine in Tiree is confined to land heavily impregnated with shell sand, thus containing a high proportion of Carbonate of Lime. The administration of crude Oxide of Iron, with or without Di-calcium Phosphate, acted as a specific in curing and preventing the disease amongst young cattle. The theory was advanced that Carbonate of Lime in excess may have rendered the Iron compounds in the soil insoluble and unavailable to herbage growing on such soils. Pine was concluded to be a form of anaemia due probably to an Iron deficiency.

While commercial Oxide of Iron was effective in these experiments in controlling the disease, it was not clear whether this was due to the Iron or to other elements present in the material. The results, however, were of value in showing that Pine was associated with a mineral deficiency in the diet.

At the same time as this investigation was

being carried out, a series of tests was conducted in Tiree by the Glasgow College of Agriculture. The results reported by Wilson (23) gave further support to the view that Iron compounds were of value in dealing with the malady. No controlled tests were reported, however.

At a later date Brown (24), in an article in the "Scottish Farmer", referred to the beneficial effects obtained in the Cromarty district of Ross-shire by feeding Oxide of Iron to cattle and sheep. This substance was found to give useful results in localities near Cromarty where pining is stated to be prevalent. No experimental data, however, were submitted in this paper.

Laboratory tests with pining and non-pining soils were made by Godden and Grimmett (25) and published in 1929. The work was done following upon similar work on "bush-sick" soils in New Zealand. Some differences were shown in the Iron and Manganese content of these soils and in the composition of the ash of oats and mustard grown in pots. These tests were of interest as preliminary observations on the question.

5. THE OCCURRENCE OF PINE IN OTHER COUNTRIES.

Under the term "Pine" one may include those conditions which are characterized by the same type of symptoms as Pine in Scotland. The chief of these are marked debility and anaemia, followed by severe emaciation. It is typical in the different countries that the stock may be grazing on abundant pasturage when they become affected with the disease, and that there is little or nothing in the general appearance of the herbage to indicate that it is inadequate for the proper maintenance and health of the stock. It is also a feature common to the different forms of the malady that it can be prevented by a change of pasture to a different soil type, and can also be cured by this means, provided the change is given in time.

As regards its occurrence in England, pining is prevalent in Northumberland on the English side of the Cheviot Hills, as described by W. L. Stewart (26). This is, of course, the same disease as on the Scottish side. There is little reference to it in other parts of England in current literature, but no doubt a form of it is known locally in many hill districts. It is the experience of the writer that wherever sheep are kept under poor conditions, the disease is liable to show itself in seasons when the stock have got run down. The disease may not be of

an endemic nature, but may take the form of a series of sporadic outbreaks.

Little is known by workers in this country about the occurrence of Pine in European countries, probably owing to the lack of accessible literature on the subject. It is possible also that a condition of this nature might be well enough known to practical stock-owners without finding its way into technical literature. The fact that the disease affects sheep more than the larger herbivora would tend to rule out considerable tracts on the continent where there are few sheep.

In parts of Holland the disease "Lecksucht" (27) occurs on poor moorland soils which have recently been reclaimed. In such cases the administration of Copper, with or without Iron, is reported to be effective in curing the animals.

"Bush Sickness" in New Zealand has been intensively studied for many years by Aston (28) and others, and appears to be very similar to Pine in Scotland. In some of the affected areas it was formerly impossible to rear sheep. The discovery that crude Iron compounds acted as a cure and a preventive revolutionised the raising of stock in these districts. Investigations have been in progress on the subject in New Zealand since 1900.

In South Australia a malady known as "Coast Disease" (29) is the cause of considerable losses.

It occurs on soils with a very high proportion of Carbonate of Lime, similar in type to pining soils in Tiree. This condition also seems to be similar in many respects to Pine in Scotland and has responded to similar treatment.

The same malady occurs in West Australia where it is termed "Enzootic Marasmus" (30). A long series of recent investigations have thrown light on some of the underlying causes of the anaemia.

The disease "Nakuruitis" (31) which is present in Kenya has been the subject of much experimental work. Successful results are reported from the feeding of Iron Salts.

Another malady which closely resembles Pine is "Salt Sickness" present in Florida (32). It is stated that a deficiency of Copper is the probable cause, and the feeding of this element has acted as a cure. Iron alone is not effective. Experiments were begun 40 years ago and are still in progress.

The above are the chief instances met with in the literature on the subject. Investigations in the different countries have not yet reached the stage when the relation between different types of pining can be established with accuracy. Any form of mineral deficiency ultimately gives rise to debility and anaemia. The precise rôle of many elements is not yet understood and the literature requires to be read with caution as the conclusions

published have frequently been upset by subsequent research.

The main work on the subject has been done in America, New Zealand, and Australia. Research in Great Britain into nutritional anaemias of live-stock under field conditions is of comparatively recent date and owes much to what has been done elsewhere.

References to the work on Pine in other countries will be made at appropriate points later in this thesis.

6. SYMPTOMS AND GENERAL CHARACTERISTICS OF BORDER PINE.

It is desirable at this stage to give an account of the symptoms and other features of the disease as affecting sheep grazing on pining land in the East Borders. The writer has made a detailed study of the matter in the course of visits to affected farms during the past four years and while carrying out controlled experiments with sheep at different seasons of the year. It is intended in the paragraphs which follow to describe the symptoms as shown by the Cheviot breed of sheep, and to amplify certain aspects later on with experimental data.

The Onset of Pine.

It is characteristic of pining that the onset of visible symptoms is comparatively sudden. Sheep which are apparently in good health and vigour are found within a few days to be in a state of decline. Any members of the flock may be affected, but there is evidence to show that sheep which are in poor condition are more susceptible than the others.

The shepherd has constantly to be on the watch for any deviations from normal health, particularly in late spring and early summer as far as ewes are concerned, as at this period the greatest

strain is imposed upon the stock. Any carelessness in herding or the want of proper oversight of each individual in the flock may lead to numbers of sheep becoming advanced in pining before it is realised that anything serious has happened.

General Appearance of Affected Sheep.

One of the first symptoms noted is that affected sheep show a falling off in vigour, and develop a somewhat tired and listless appearance. They tend to hang their heads and to move about more slowly, lagging behind when the flock are driven. They can be more easily caught and held than other sheep. The step becomes slow and short and if driven for any distance they lie down in an apparently weak condition. The short, slow step is always a tell-tale symptom.

There is never at any stage any stiffness of the limbs or inco-ordination of gait such as is sometimes found in other ailments. An animal showing stiffness is not regarded as a typical piner.

As the disease progresses, the animals become extremely weak and may scarcely be able to rise. In bad cases, particularly among ewes, the head and neck are frequently extended forward when the animal is made to walk. In experiments to be referred to later, pining animals were frequently in a state of collapse and had to be carried in for treatment.

DECR 16th 1935.

HEAD OF A BAD PINER - (Cheviot Hogg).

Note dark colour of face and head, matter at eye, also sunken eye.

DECR: 16th 1935.

HEAD OF A NORMAL HOGG.

Note clean white hair, bold eye, erect ears.

The early symptoms are sometimes difficult to recognise, although to the experienced shepherd they present little difficulty. It must be remembered that certain states of the weather produce well marked reactions upon the appearance of hill sheep, particularly in winter. A shepherd in pining country however, can readily pick out the first signs of pining at any season.

The Hair on the Face.

The hair of the face usually assumes a dirty appearance instead of the clean white colour in the healthy animal. This discoloration gradually extends over the face and head and around the base of the ears. Sheeps' faces naturally tend to take on a rather dark shade in the fall of the year owing to changes in the weather and the gradual lowering of the plane of nutrition. Many other signs will also be present, however, if the sheep are in health, making it easy to differentiate.

In spring or early summer the piner is recognisable because it retains the old hair on the face and head thus giving an unhealthy brownish colour. Thriving animals at this season begin to cast the old hair which can readily be rubbed out by hand. Their faces become clean and white due to the arrival of the new crop of hair.

In pining sheep, the hair, instead of being

laid back against the skin, tends to become erect or staring. This usually begins at the muzzle and works back to the forehead until the whole face and head are involved. In this state, if accompanied by a dirty colour, the animal is far gone in pining. The dirty colour of the face and staring hair are due to the drying up of the oily secretions of the body. The oily matter solidifies on the hair and forms a black deposit which is well seen when examined under a microscope.

The Wool.

In the healthy animal the wool has a natural lustre and resilience and stands well up from the body. It is of a creamy colour when the fleece is parted. This is due to the secretion of yolk, or lanolin, from the skin which assists in running off water from the wool fibres. This creamy colour extends to the outside of the fleece and gives it "bloom". It is very noticeable in early summer when the sheep are rapidly thriving and new wool is growing fast.

In pining sheep, on the other hand, the secretion of yolk ceases and the wool becomes dry, hard and lustreless. It becomes a white chalky colour inside the fleece, while on the outside it gets dark or bluish. The fleece becomes sunken and matted. Affected animals can as a rule be picked

out from the flock by the dark colour and sunken nature of the fleece.

Wool grows rapidly in late spring when the new season's grass has become plentiful. The new growth of wool at this stage can generally be seen as a distinct layer next the skin, which by the end of June will usually be about 1 - 1⅛ inches long. This is termed the "rise" and it enables the shears to be got under the fleece in the process of shearing. Unless the "rise" is present in the fleece, the sheep cannot be shorn. When sheep pine in spring, however, the growth of wool ceases. There is little or no "rise" when the fleece is examined. The wool remains tightly adherent to the body and around the neck. Such sheep cannot be clipped until recovery in health has enabled a fresh growth of wool to take place.

The Skin.

The skin of the body in pining sheep instead of being a flesh pink takes on a bluish tinge, probably due to the anaemia. This changes later on to a brown colour, due to the surface becoming covered with a brownish scurf as a result of the drying up of the yolk.

The skin itself in bad pining cases becomes as thin as paper and remains adherent to the ribs. The thin paper-like skin is specially noticeable on

the thighs and is very characteristic of this disease.

The Eyes.

There is nothing so indicative of health and well-being in sheep as a full bright eye. The healthy eye attracts attention by its lustre and boldness. In the pining animal it is lifeless and dull. They gradually become sunken and the lids become constricted which tends partially to close them. Pining sheep are typically "small in the eye". The eye-lids lose their elasticity and are more difficult to turn over when it is desired to examine the lining membrane.

A noteworthy feature is that if a pining sheep is watched at the commencement of the trouble it will be seen constantly to blink its eyes or to close them for several seconds at a time. Drops of water will be seen occasionally to fall from the mouth. This is typical of the malady in the East Borders and is quite a distinctive symptom not found in other ailments. There are no dropsical swellings about the head or other parts of the body.

The white of the eye, or Sclerotic, is, in the healthy sheep, of rather a dark bluish colour. The conjunctiva which covers the surface shows numerous red veins which stand well up. In sheep which have been pining for some time, however, the white of the eye becomes pale blue or whitish, while the red

veins are absent.

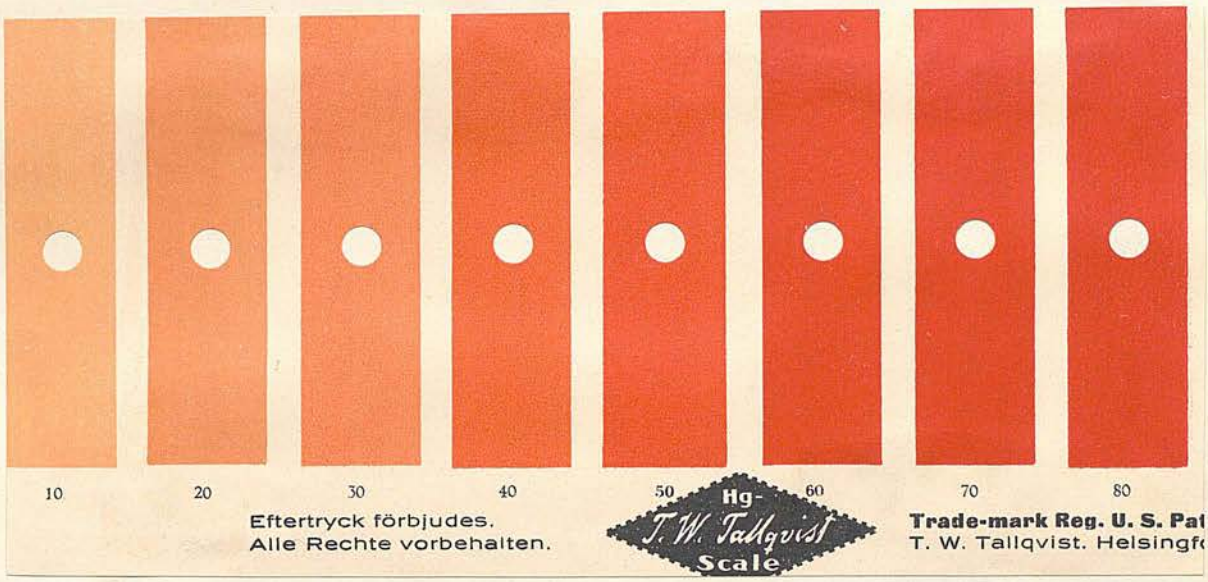
The Conjunctiva.

In all forms of anaemia there is a tendency for the lining membrane of the eye-lids, or conjunctiva, ultimately to become pale and bloodless. This is specially true of Pine where it often reaches unusually low limits. When visible symptoms of Pine are first noted, the conjunctiva may be quite normal in colour. As the disease progresses, however, the membrane becomes a faint pink and finally almost all trace of colour disappears. The length of time the animal has been pining can often be approximately determined by an examination of the conjunctiva.

It may be stated in passing that other visible membranes of the pining animal, such as those of the gums, lips, and nostrils, also show an anaemic condition.

The degree of colour in the conjunctiva is a useful and fairly accurate guide to the condition of sheep. In the various experiments to be described, records were kept on this point. It was felt desirable to have some kind of standard colour scale in order to take comparable readings, and for this purpose the ordinary Haemoglobin scale of Tallqvist was employed. The colour scale is shown overleaf.

Colour Scale.



In the case of sheep in a thriving state, the colour of the conjunctiva is usually around 40 or over. Hill sheep in winter often fall below this figure. Sheep which have been pining for some time show a colour of about 30, while bad piners go down to 20 or under. As there is sometimes a slight variation in the colour of the left eye compared with the right, it is necesaary to take an average of the two readings.

The chief value of the scale is in enabling readings to be made at different stages of an experiment and to make comparisons between different experimental groups. It has been found that an improvement in the condition of pining sheep is

gradually reflected in a higher colour reading.

Water and Matter at the Eyes.

A discharge of matter from the eyes is often present in pining sheep, particularly in winter, and is usually associated with lachrymation. This matter arises from an inflammatory condition of the mucous glands causing an increased flow of material. The matter accumulates on the hair at the anterior corner of the eyes and in the course of time makes a well-defined mark. As pining continues, the matter may extend all round the eyes both above and below, and in extreme cases may seal up the eye itself. In badly pined lambs this may give rise to eye ulcers.

Watering at the eyes and the accumulation of matter is not exclusively a symptom of pining. It occurs in a mild form with any hill sheep under hard conditions resulting in the lowered resistance of the animal. Prolonged exposure to cold winds at high altitudes is a frequent cause. Cold wet weather continuing for long periods will also cause these symptoms. On the other hand, a period of dry frosty weather is beneficial and puts hill sheep in a thriving state. Their faces become whiter and glossier and any matter tends to dry up and fall away.

Matter caused by bad weather is seldom excessive in quantity. Where it saturated the hair

right through to the skin, however, it is usually a sign of pining.

The Abdomen.

Nothing is more characteristic of pining in adult sheep than the drawing up of the flank and belly. This appears to be due to interference with the digestive processes and invariably occurs at an early stage in the course of the malady. The sheep lose the belly, or get "gutted". They are thereby completely altered in appearance. There is no arching of the back and no indication of any painful effects.

In the case of pining lambs or hoggs a proportion of them instead of getting gutted in the belly get pot-bellied. These are the greedy feeders which continue to ingest large quantities of food and thereby suffer from a type of indigestion.

Appetite.

The gutted state of the belly which is typical of adult piners is associated with diminished appetite. There may be no decrease in food consumption at the beginning of the ailment; indeed, it is often suggested that piners always continue to eat readily. This is not so, however. There is a gradual falling off until in the latter stages the animal is unable to eat at all. It may exist for a

week or more without feeding. A diminished appetite following upon derangement of the processes of food assimilation is a common symptom of mineral deficiency.

The derangement of the system is accompanied by several signs. A badly pined animal tends to lose portions of food from the mouth when chewing the cud. This collects as a green deposit round the mouth and is one of the final symptoms. They are shy to eat supplementary feeding such as hay or concentrated foods and will not take readily to mineral feeding. This is one of the difficulties in treating piners and points to the importance of preventing the trouble rather than curing it after it has arisen.

Constipation.

An important symptom is that a certain degree of constipation is always present. The only exception is in early summer when new, fresh grass is coming away and may cause disrrhoea. Pining sheep, however, are much less affected at this season than others, the majority remaining dry. The malady is termed a "dry" pine to distinguish it from other wasting diseases which are accompanied by scouring. Should a piner begin to scour before it is too far gone, it is usually taken as a hopeful sign. The animal may take a turn for the better thereafter.

At the last extremity, the piner usually scours on the point of death.

Respiration.

With the development of Pine, respiration slows down and the breathing becomes more shallow. A comparison between 20 healthy Cheviot sheep and 20 pining Cheviot sheep taken at rest on the same day was as follows :-

	Respirations per minute.
Healthy sheep -	72
Pining sheep -	44

Repeated tests have comfirmed this result. In the case of Enzootic Marasmus, on the other hand, Filmer (30) states that the rate of respiration in that disease remains normal.

The rate of respiration in piners is little affected by any exciting causes, in marked contrast to the extreme variability in respiration when normal hill sheep are disturbed. The animal seems intent on husbanding its small store of energy to the utmost. In the face of undue exertion, therefore, the piner lies down and remains in an apparently passive state with little or no increase in the rate of respiration. Some writers have referred to symptoms of breathlessness. There has been no confirmation of this in these tests.

When pining sheep improve there is a gradual

increase in the rate of respiration. This is almost a constant feature, and it has been found possible in these experiments to judge the progress of different groups from the rate of respiration alone.

Pulse.

The main feature of the pulse is its weakness. In some pining sheep it has been found to average 110 beats per minute, but in many cases it is so faint as to be scarcely perceptible to the finger tips.

Temperature.

The temperature remains normal, about 104°F. In observations on a large number of pining sheep no disturbance in temperature was found.

The Blood.

There is an apparent diminution in the volume of blood which is seen from the small quantity produced when a pining sheep is killed. The animal does not easily bleed from cuts, and when tags have been inserted in the ears there has usually been no bleeding. Whether there is actually a reduction in blood below the normal proportion has not been determined. The blood volume is usually considered to be regulated in proportion to body weight. With pining sheep in an emaciated state it is therefore to be expected that the volume will be diminished. The

subject, however, is open to investigation. It has a considerable bearing on the question of blood analyses.

There is a gradual decrease in the number of Red Blood Corpuscles. Fraser of Cambridge (33) gives the average number of red cells per cubic millimetre of blood in the adult sheep as 10.35 million. Stewart and Piercy of Newcastle (26) found in an experiment that the average number in a group of healthy hill sheep was 10.52 million, while in a corresponding group of pining sheep it was 5.77 million. This represents a reduction of 45 per cent. which is probably rather an extreme example.

The percentage of Haemoglobin usually shows a corresponding decrease. In the same experiment, Stewart and Piercy ascertained the percentage of haemoglobin to be 11.43 in the healthy group of sheep compared with 6.12 in the pining group.

Regarding White Blood Cells, or Leucocytes, it was found that there was a decreased proportion of Neutrophiles and an increased proportion of Lymphocytes and Eosinophile Cells. The total number of White Blood Cells was somewhat less than in the blood of normal sheep.

Accompanying the above changes there is sometimes a disturbance in the serum-calcium level of the blood and of blood Phosphorus. To refer again to Stewart and Piercy's experiment, serum calcium in the

healthy group amounted to 9.2 milligrams per 100 c.c. of serum, and in the pining group 8.3 milligrams per 100 c.c. The figures for inorganic Phosphorus were 5.35 milligrams per 100 c.c. of blood in the healthy animals and 4.97 in the pining animals. A somewhat similar result was found in experiments referred to in this thesis.

Regarding blood changes in general, the blood picture largely depends on the stage at which tests are made. If pining has only newly developed there is not the same differentiation as at a later stage. The Red Cell count and Haemoglobin may in many cases remain normal even though clinical symptoms have developed.

Emaciation.

As the name suggests, pining is a wasting disease, though in the early stages there may be little loss in weight. It will be shown later, indeed, that a growing hogg may exhibit visible symptoms and still continue to make an increase in live-weight. This phase, however, soon gives place to a decline. The loss of condition gradually goes on until a stage of extreme emaciation is reached when the animal is merely skin and bone. In this state all organs of the body become depleted, and the skin itself is drawn upon to furnish sustenance. The thin condition of the skin has been alluded to

previously. The digestive tract is more or less empty and the net result is a condition of extreme lightness in which an adult sheep can be lifted off the ground with comparative ease.

The disease follows a slow lingering course. Sudden death is the exception and in such cases is usually due to some other cause. The animal continues to exist for months before succumbing.

Post Mortem.

Stewart and Piercy (26) found evidence of parasitic gastritis in each of 13 sheep affected with Pine. The mucous membrane of the fourth stomach showed a thickened and roughened appearance which was absent in healthy sheep. In some cases it was slightly inflamed due to the parasites.

The stomach wall of pining sheep was often dropsical and the Lymph glands soft and likewise dropsical. There was frequently much fluid in the abdominal cavity. According to Filmer (30) similar symptoms to the above are commonly found in Enzootic Marasmus.

The heart was found by Stewart to be often flaccid and pale and surrounded by fluid. In a few cases it was enlarged. The other organs appeared to be normal, there being no noticeable change in the liver except that it was small and pale. In both Enzootic Marasmus and Bush Sickness on the other hand,

the liver is stated to show marked fatty infiltration either of the whole liver or in localised areas.

Stomach and Intestinal Parasites.

In the 13 pining sheep examined by Stewart and Piercy, infestation with parasitic worms was present in every case. The numbers ranged from 6,000 to 60,000 per animal. These were chiefly the Lesser Stomach Worm (Ostertagia circumcincta) with smaller numbers of the Larger Stomach Worm(Haemonchus contortus) and others. Stewart and Piercy concluded that pining is usually a form of parasitic gastro-enteritis. This is an interesting point as hill pastures on pining farms with their relatively high stocks of sheep do carry a considerable population of worms.

From experiments carried out by the writer it seems unlikely, however, that worm infestation is the primary cause of pining. The disease has been cured and prevented in these experiments by minute quantities of mineral compounds which have never been regarded as having any anthelminthic properties. Animals in a state of collapse have made spectacular recoveries time and again without any change of pasture or other treatment. All domestic sheep carry parasitic worms and it has been shown that large numbers may often be present without apparent effect upon the health of the animal. Worms may hasten the onset of

the

malady and may retard recovery in practice, but they are of secondary importance to the fundamental cause of the disease which is a nutritional deficiency.

Summary of Pining Symptoms.

The clinical symptoms of Pine at an early period are set down hereunder as a guide to the diagnosis of the disease on its first appearance.

Early Symptoms.

1. Rather listless and dull appearance.
2. The step is rather slower than in normal sheep.
3. The wool is rather dry and lustreless; dark or bluish on the outside of the fleece.
4. Wool sunken.
5. Skin of the body bluish instead of pink.
6. Hair on the face dirty.
7. Hair on the face staring.
8. Eyes blinking when the sheep are allowed to stand at rest.
9. Eyelids constricted; the eye orbit contracted.
10. Matter collecting at the eyes. There may be no matter in summer.
11. Paleness of the conjunctiva if pined for some time; normal colour if just beginning.
12. Slightly gutted state of the belly. Lambs or hoggs may be pot-bellied.
13. Slight constipation.
14. Diminished rate of respiration compared with other sheep.

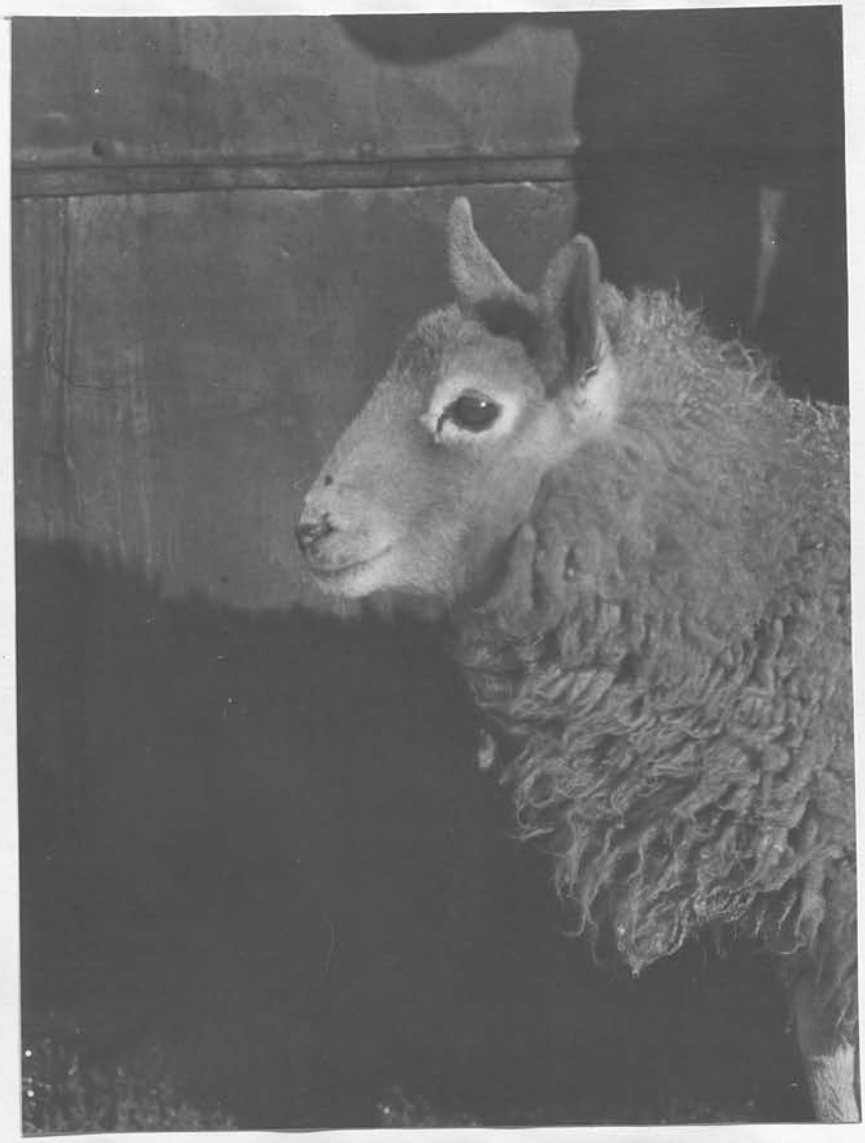
All of these symptoms may not be present at the commencement. There may, for example, be no gutted state of the belly, the face may be fairly clean and white, and the animal may be fairly active. If symptoms 3, 4, 8 and 9 are present, however, it would indicate Pine.

Later Symptoms.

1. All of the foregoing symptoms present.
2. Extreme dejection and weakness. The animals hang their heads.
3. The animal lies down if driven hard.
4. The neck may be outstretched in walking.
5. Profuse water and matter at the eyes, in winter.
6. Skin on thighs and body extremely thin.
7. Skin of the body bluish or showing a dirty brown scurf.
8. Pallor of the conjunctiva and all membranes.
9. Eye sunken and dull.
10. Loss of appetite.
11. Extreme emaciation.

Signs of Recovery from Pine.

During the course of treating large numbers of pining sheep on different farms, special note was taken of the signs which indicate that sheep are on the mend. These are set out in tabular form for the sake of clarity.



A HOGG RECOVERING FROM PINE DISEASE.

Note the ring of white round the eye and base of the ear.

Note also the brightness of the eye.

1. The belly begins to fill out. Lambs or hoggs which have been pot-bellied return to normal.

2. The matter around the eyes dries up.

3. A white ring appears around the eyes and the base of the ears, showing that the hair is beginning to clean up.

4. In spring, the hair on the face and ears comes out if rubbed.

5. The wool around the neck can be peeled off. The wool of the body begins to rise.

6. Yolk is secreted from the skin and begins to saturate the wool fibres. The outside of the fleece gradually becomes a yellowish or creamy colour.

7. The conjunctiva and other membranes become a deeper colour.

8. The animal improves in vigour and activity and holds the head more erect.

9. The rate of respiration increases.

7. THE INCIDENCE OF PINE IN THE BORDERS.

Pining in the Borders is mostly confined to sheep. The incidence under practical conditions is very variable. On 12 farms from which figures are available the average incidence in 1935 was 3.0 per cent of the ewe stock. In one case which came under the observation of the writer the incidence was 15 per cent. It will be realised, of course, that every effort was made on these farms to prevent the disease.

Where no preventive measures are taken the case is entirely different. In experiments conducted by the writer in three different seasons in which Cheviot hoggs bred on the farm were confined on pining land for several months without a change, the results were as follows :-

	Pining Hoggs per cent.
1935	86
1936	73
1937	90

The average incidence of pining was 83 per cent. In no year did the test continue longer than four months. With a longer period there would no doubt have been an increase. This result confirms the opinion of flock-masters that the majority of hill stocks in the East Borders would die out within two years if kept on pining land without a change.

As regards the susceptibility of other stock to pining, cattle occasionally show it but the numbers are seldom high. Horses are not known to take the disease.

Breeds of Sheep.

While all modern breeds of sheep without exception will contract the disease on pining land, there are differences in susceptibility among the breeds. It is not easy to assess the precise susceptibility as this is bound up with the suitability of grazing conditions for a definite class of sheep. As far as the East Borders are concerned, the South of Scotland Cheviot is undoubtedly the most resistant of any breed. This has been proved repeatedly by the experience of farmers, many of whom have discussed the matter with the writer.

The South country Cheviot is comparatively small and matures somewhat slowly, and therefore makes relatively smaller demands upon nutrition. They are adapted to the grassy type of vegetation at moderate elevations, and therefore are at home in the locality, where indeed they have been bred for generations. They are full of nervous energy and are extremely active in ranging over the ground. In this characteristic the breed is pre-eminent.

The Blackface on the other hand is not so well suited to the grazing conditions of the area, as

the heather and other herbage associated in its best form with peat is not present to any extent. It is a well-known experience that a hill farm which has carried only a second-rate stock of Blackfaces may carry a first-class stock of Cheviots when changed over to that breed. Blackfaces, while adapted to stand exposure at very high altitudes, are a slower and lazier class of sheep under conditions in the East Borders. On the grassy slopes of the pining area they tend to lie about more than Cheviots and do not obtain a change of herbage to the same extent. This tends to hasten the onset of the disease.

The larger breeds of sheep such as the Half-bred and the North Country Cheviot are definitely more susceptible whether on hill-land or arable land. They have bigger frames, are more prolific, and produce a larger class of lamb. Any deficiency in mineral nutrition more readily shows up. They require, therefore, heavier land and a higher standard of feeding in winter. These breeds are occasionally run on hill-land in the Borders where there is sufficient arable ground to provide wintering in the form of a moderate allowance of roots and hay, and the advantage of rotation grass in spring if required.

Sex.

While sheep of either sex are liable to Pine there is on the whole rather a greater tendency

among males such as wether lambs and tups. Tup lambs, after weaning, are commonly found to be specially prone to the trouble. The male is stronger in the bone and requires a greater supply of mineral material for normal growth. This is accentuated in the case of young tups. It is interesting to note that on one farm, the only cases of pining occur in tup lambs, other classes of sheep being invariably healthy.

Incidence in Lambs according to Live-weight.

It may appear contradictory to the foregoing but it has been found in these experiments that lambs below the average in live-weight are as a rule more susceptible, after weaning, than those which are above the average in live-weight. It has been repeatedly found that the smaller lambs in a group have been among the first to pine and to take the disease in a more severe form. Twin lambs, gimmer's lambs, and any badly-nursed lambs are in practice found to be least resistant. These lambs are nearer the border-line of debility at weaning time.

Age.

While on typical pining farms all ages of sheep are liable to the trouble, the younger ages often show the highest incidence. Indeed, on farms where pining is of a mild type the disease is mainly

confined to these ages, namely, lambs, hoggs and gimmers.

The highest incidence is found among lambs during August, either before or after weaning. As the lamb is obtaining less of its nourishment from the ewe and more from the herbage, it consequently is more liable to feel the effects of a deficiency. Many farmers have had the experience of keeping lambs back from the first sale at Hawick at the beginning of August with the intention of sending them to the second sale, a fortnight later. These lambs have been visibly healthy and have continued to run with their mothers. They have become so affected with the disease in the interval, however, as to be unfit for the sale-ring and it has been necessary to send them away for a change. Pining may break out at any time during August with disastrous effects on lambs. All ewe-lambs which are being retained for stock must be given a change during the month.

The disease in older sheep is usually most prevalent where the animals are in a reduced state as after a bad winter and spring, as will be referred to later.

Ewes which get into very poor condition through nursing lambs are also readily affected. These have been cured in considerable numbers during the course of this investigation. It is considered by many farmers that this form of debility is rather

different from true pining. There seems little doubt, however, from the fact that the same treatment has acted as a cure in both cases, that it is the same, or a very closely allied, form of anaemia.

The total number of ewes treated by the writer for pining during the spring and summer periods in the last three years was 113. These were located on 8 farms. Recovery took place in 103 cases, the remainder succumbing to some form of intercurrent disease.

The Type of Cheviot Sheep.

The problem with hill sheep is how to improve the economic qualities and at the same time retain sufficient natural vigour and hardihood. Some sacrifice in health and resistance to disease is sure to follow if the first is overdone. It is the opinion of many experienced farmers that many local strains of the Cheviot have become rather finely bred for commercial requirements. This subject is constantly under discussion and is recognised as one of the chief problems of present-day breeding.

As far as pining is concerned there are one or two characteristics in Cheviot sheep which have been observed to have some measure of correlation with the malady.

A sheep which carries a fleece of great density and fineness such as is often found in East

Border Cheviots is rather more susceptible than the rougher-coated type. Evidence of this has been found in these experiments. The fleece of the dense, compact type is invariably short. In the case of hoggs in winter it has been found by measurement to be 2 - 2½ inches long, compared with 3 - 3½ inches for rougher-coated sheep. In the well-bred animal it gives an appearance of quality and finish which is most attractive. Quality in this case, however, has probably been pushed rather far. Lambs bred off this class of sheep are poorly clad at birth and stand a relatively poor chance in bad weather compared with lambs carrying longer wool. For thriving purposes at all stages a fleece not too closely planted and of good length is regarded as the more desirable for commercial purposes.

A plentiful covering of strong hair of good length on both the inside and outside of the ear is essential. Ears which are well-haired indicate that there will be a good covering on other parts of the body and also a lengthy type of fleece. Where the hair is very short and silky on the outside of the ear there is often little or none on the inside, and the ear is given a red appearance when seen from certain aspects. This is invariably a sign of tenderness among the stock. The ear-covering, therefore, can be taken as a pointer to the general character of the sheep.

If there is a trace of tan colour in the hair of the legs, ears, or face, this is regarded as an indication of hardiness and resistance to pine, although these points disqualify according to pure-bred standards. The tan colour represents a link with the hardy ancestors of the breed.

The development of bone is closely associated with health and vigour in live-stock. The better boned the stock are the more likely they are to grow and thrive satisfactorily. Fine-boned sheep are often lacking in stamina and show a greater tendency to pine. Owing to the light, shallow nature of the soil, sheep raised in the East Borders are inclined to be rather deficient in bone. This is a matter of common observation and McGowan and Smith (8) are quite wrong in stating that the sheep are as good in this respect as in other areas.

These various characters generally go together. Fine-haired sheep usually carry a short dense fleece and are often rather lacking in bone. This is the fine-bred type which is largely represented in the show-yard but upon the utility of which the commercial farmer has considerable doubts.

Conformation.

Little need be said on the question of conformation. It has sometimes been argued that to secure ewes of good milking type something of the

wedge-formation is desirable in hill ewes after the manner of the milk cow. This, however, leads to a falling off in constitution. The animals tend to be narrow chested, lighter in the body, and longer in the leg, and are less able to withstand severe conditions. This is the type that is most liable to pining. Many observations made during the course of the investigations amply confirmed this point. It must be remembered that the ewe has to live herself in the first instance before she can nurse a lamb, and the qualities that ensure vigour and hardihood in the mother are of first importance. The thick blocky type of ewe is therefore necessary.

In practice, the milking qualities of the ewe-stock are maintained by selecting the strongest and best of the ewe lambs for breeding purposes. These will generally be the progeny of the best milkers and those which are well suited to the ground. If there should be a tendency towards the wedge-type this is counteracted by breeding measures.

Periods at which Pining develops.

Outbreaks of pining are to some extent modified by the system of management adopted. In the Cheviot area the periods are approximately as follows :-

Lambs - August and September

Hoggs - February to April

Ewes - (a) March and April

(b) June and July

These periods may be regarded as coinciding to some extent with checks imposed upon the animal system. In the case of lambs the milk supply has been withdrawn in August. They are changed during the month and this usually keeps them going as hoggs throughout the winter. At the end of winter, however, following upon the comparatively poor quality of the food supply, a tendency to pining may show itself.

Ewes tend to improve in condition from August onwards, due to the withdrawal of the lambs. During late winter, however, when they begin to get heavy in lamb the strain makes itself felt and pining may occur in March and April. There seems little doubt that this has a close connection with normal pine, although some farmers do not regard it so. When spring conditions arrive with a supply of new grass on the hills, the ewes abtain a valuable change of meat which tends to put them into a thriving state. After suckling lambs for some weeks, however, the drain on the system is too great and the malady may appear in serious proportions in June and July.

Effect upon Young Lambs.

If the ewe pines early in spring, as during the month of March, the lamb will be born weak and

may die at birth. Should it survive it will be worth little or nothing. Should a ewe pine immediately before lambing the lamb is usually strong and healthy but must be taken off the ewe to assist her recovery. Where, on the other hand, pining takes place after a lamb has been nursed for some weeks the lamb is weaned off and may fend for itself moderately well thereafter, though it will likely be of secondary value.

An outbreak of pining among ewes, therefore, has serious consequences in the depreciation of the lamb crop. A wether lamb is worth on the average about £1 in the normal way at weaning time. The progeny of a pined ewe may be worth no more than 7/6, or may be lost altogether.

When a ewe pines, the lamb as a rule pines also. Very often the lamb begins to pine before the ewe. The probable explanation is that the quality of the milk is inferior and brings about the onset of the disease. A reduction in the quantity of milk is not always apparent in such cases. Such lambs have often been cured by the administration of Iron compounds, etc., without the supply of milk in any form. This appears to afford evidence of a defect in the quality of the milk.

Pining tends to recur.

The prevailing experience is that a sheep which has once pined is more likely to take it again at a later period. On account of this, it is sometimes the practice to draft out ewes that have pined and sell them off so as to avoid a recurrence. It is thought that a weakness tends to persist in such sheep which is quite understandable if they have been much reduced in condition. On the other hand, the ewes cured in these experiments by mineral feeding or medicinal dosing showed no greater tendency to pine in the following season. The strong and healthy nature of the lambs of these ewes was indeed a subject for comment.

Bought-in sheep pine less.

Sheep which are bought in are much more resistant than those bred on the ground. They are better supplied with mineral material, and the difference in resistance is commonly stated to last for one year. On one or two of the smaller farms a flying stock of ewes is run on pining land and sold off after one or two years. No pining has occurred on these places since this system was adopted. One farm, much addicted to pining, and carrying a stock of 460 Cheviot ewes, had a new stock put on when the farm changed hands. This was found to reduce the incidence of the trouble. Care has to be taken to

know something of the land from which the fresh stock are taken. If they have been bred on heavier land they do not do so well.

The question of acclimatisation bulks largely in most sheep-farming districts. In most parts of Scotland it is regarded as a first essential that the stock be bred and reared on the ground. The sheep spend their lives on the same section of the grazing. Such flocks acquire a value far above their sale-ring value. In the East Borders, however, stock more readily get acclimatised than anywhere else and are not given fancy values. The hill land in most cases is very accessible to sheep which appear to find the recognised beats very readily. The practice in the district is not to run sheep on the same heft or hirsel throughout their lives but to change them about on different ground according to age. Thus there is a recognised section of the farm set apart for hoggs, another for gimmers, and so on. It is a comparatively simple matter, therefore, to introduce new lots of stock as occasion arises.

The area is largely free from tick infestation; Louping Ill and other tick-borne diseases are therefore comparatively little known. Stock introduced from another area are therefore not liable to suffer from diseases of this type.

In this particular area, therefore, it may be said that stock do not acquire benefit from acclimat-

isation as far as pining is concerned. The stock on the ground is indeed more liable to the disease.

Summary.

1. The average incidence of pine disease in the affected area in the East Borders is about 3 per cent of the ewe stock. Where sheep were kept on pining land without a change, however, the average incidence in three experiments was 83 per cent.

2. All breeds of sheep are susceptible, but the South Country Cheviot is probably the most resistant.

3. The younger ages of sheep usually show a higher incidence of the disease, lambs after weaning being most subject.

4. Finely-bred sheep are probably more susceptible than the rougher bred type. A conformation that ensures vigour and constitution in the ewe tends to give greater resistance.

5. In practice, ewes are most liable to pine during March and April and in June and July. Hoggs tend to pine in February, March, and April.

6. Bought-in sheep are less subject to the disease. This resistance may last for about one year. There is no acclimatisation value in sheep-stock as far as pine disease in concerned.

8. FACTORS INFLUENCING PINE.

The factors influencing pine are many and varied and include anything that has to do with the health and well-being of sheep-stock. Most practices in the area have a bearing on the question and it is necessary to refer to these in some detail.

The Soil.

Pining is largely influenced by the soil, owing to its effect upon the feeding quality of the herbage. More than any other single factor the soil has a dominant influence. The area in the East Borders where pining is endemic is mainly situated on soils derived from Andesite rocks. These soils are for the most part shallow and coarse in texture with much unweathered material. They are loose and open and liable to drought. Large stretches of hill land have a covering of only three or four inches of soil resting directly on the rock.

Areas of shallow land are recognised as being of poor feeding quality and chiefly responsible for giving rise to pine. Areas of deeper land with a finer texture are often found at lower elevations but may also be found high out. These are reckoned, as a rule, to be richer in mineral material and to help in counteracting the relative poverty of the shallow ground. All the deep land, however, is not necess-

arily of this character. In the course of the enquiry it was found that pining was most severe on those tracts where the soil was either very thin and coarse, or, if fairly deep, was unduly light and open. If situated on a steep slope the trouble was often accentuated. Pining land may be separated from healthy land by a stream or fence or by a line of demarkation in the herbage. These distinctions are due to changes in the quality of the underlying soil.

Arable land is liable to pine just as in the case of hill land, if situated on a similar type of soil. In fact it often tends to pine worse owing to the effects of increased aeration and leaching produced by cultivation. On some arable fields, ewes and lambs cannot be kept longer than three weeks without a change, otherwise pining may develop. If the arable land is superior in quality to the pining hill ground, however, it will provide a change for the stock and form a valuable asset in dealing with the trouble.

Pining is not confined to the Andesite formation. It is found on all geological formations in the Border Counties although not on such a widespread scale. A few farms here and there have particular hirsels affected. Wherever the soil is thin and poor, pining may be looked for.

Further details regarding soil and geological features are given more fully in a later section of

the thesis.

Herbage.

The East Border hills are covered with a grassy type of vegetation and this is a predominant feature of the herbage of the pining area.

On the shallow land the typical vegetation is an association of Agrostis with Sheep's Fescue in which Smooth Stalked Meadow Grass and Fluff Grass are always more or less present. Other species of plants are not at all frequent except Wire Bent Grass, or Nardus, which often dominates considerable stretches. This shallow land is known as "sweet ground" from the fact that the herbage never grows very rough and is mainly composed of the finer grasses. It is kept short and leafy by the constant grazing of sheep. These areas constitute the chief pining portions owing to their relative poverty, but at the same time they are the most attractive parts of the grazing to sheep.

Deep-land vegetation is found on every hirsel and is of different types according to the kind of grass most prevalent. The areas are fairly well defined, and consist of :-

(a) Areas with short leafy herbage of the Agrostis-Fescue type. This accounts for a very small acreage in pining country.

(b) Areas under Tufted Hair Grass.

(c) Areas under Molinia or Flying Bent.

(d) Areas under a mixed herbage of Tufted Hair Grass, Molinia, Spret Rush, etc..

(e) Areas under Heather growing on moss. This is as a rule present in isolated spots.

The finer bottom grasses occupy a relatively small place in the vegetation of the deep-land areas. Nevertheless, the feeding properties of these grasses is reckoned to be higher than on the shallow ground. The main preoccupation of the shepherd is to get the sheep to work through the deep land for a portion of each day in order to keep them in health.

The chief draw-back is often the relatively small proportion of deep land that occurs among the pining tracts. Not only so, but there is usually only a small amount of deep land that is short-grazed and leafy and attractive to sheep. The sheep are, therefore, forced on to the sweet ground which pines worst. Heather is almost entirely absent on many farms. It is felt that its presence would be a great help, but that it would not altogether eliminate the trouble, unless growing on very deep moss.

Particulars were obtained regarding the amount of deep-land and shallow-land on eleven pining hill farms with a total acreage amounting to 12,990 acres of hill land. An approximate estimate was formed of the constitution of the grazings.

Details are as follows.

CONSTITUTION OF HILL FARMS

AVERAGE OF 11 FARMS(1,171 acres)

	Per Farm acres	Per Cent
Acreage of Deep-land Vegetation	269	23
Acreage of Shallow-land Vegetation	902	77
	1,171	100
Acreage of Heather	70	8.1
Acreage of Moss	44	5.5

On the average, therefore, 77 per cent of the hill land on these 11 farms is estimated to consist of shallow-land vegetation, while only 23 per cent is deep-land vegetation.

Heather is found on only 8.1 per cent of the land. Four of the farms have no heather at all, while three farms have less than 25 acres. Its scarcity is largely due to the heavy grazing with sheep. The heather is partly on moss but a great deal of it consists of lea heather of a poor type.

Moss accounts for only 5.5 per cent of the total acreage. It is altogether absent on five farms apart from the type of surface peat associated with Molinia, and the thin humus deposit that occurs under grass at high altitudes. On only one of the 11 farms is there any appreciable quantity of draw moss (Eriophorum) which forms so valuable a part of the

grazing in many hill districts in early spring.

The above estimate may be taken as fairly representative of the pining area as a whole.

A comparatively small proportion of pining land may affect a whole group or hirsel of sheep. In one case, namely, The Arks, only 25 per cent of the land on one hirsel is reckoned to be pining but as this is the land on which the sheep tend to settle and feed most, the whole of the flock is made liable to pining. In such a case the fencing off of the unsound portion would restore the value of the grazing. This has been done elsewhere in several instances.

Pining is influenced by a combination of factors relating to soil and herbage. The presence of a limited area of deep-land vegetation, an open and coarse soil, the dominance of Nardus over large areas, the small acreage of heather and moss, and the relatively high rate of stocking, all tend to bring about a lowered standard of mineral nutrition in the sheep.

Further particulars regarding Herbage are given in a later section.

Rate of Stocking.

It is believed by many farmers that were the rate of stocking reduced the health of flocks would be benefitted and losses from pine would be less.

There is no doubt that the pasture would keep cleaner under smaller stocks, and the supply of winter meat would be more abundant. The spread of Nardus would also tend to be arrested as mentioned by Fenton (34) and other writers. It may be noted that the present high rate of stocking has been in existence for at least 150 years and has undoubtedly caused a considerable drain on the mineral resources of the soil.

On the other hand, lighter stocking would allow the rough ground to increase and force the sheep on to the shallower and more pining areas. For this reason, several farmers deliberately run heavier stocks than they otherwise would. This practice, however, would appear to be a last resource. With the methods of preventing pining worked out in the course of the experiments to be described later, such a means of control is now entirely unnecessary.

Less sheep and more cattle would be helpful although any great change in this respect is difficult on hill farms.

A special enquiry was made regarding the rate of stocking on East Border farms and this, together with other details, is shown in the undernoted table. The farms form a large and representative group in the district.

Data relating to each farm included in the survey are given in Appendix (1) on page 246.

RATE OF STOCKING
ON EAST BORDER FARMS

No. of Farms surveyed	26
Total Acreage of Hill Land	27,474
Total No. of Ewes, Gimmers, and Hoggs	23,184
No. of Ewes, Gimmers, and Hoggs per acre	0.843
Lamb Crop, per cent (1935),(at cutting)	92.38

The rate of stocking works out at 0.843 sheep (not including young lambs) per acre of hill land; or 1.18 acres of hill land per sheep. 8 out of the 26 farms have a stocking of one sheep or over per acre, while 14 farms have a stocking of less than .843 sheep per acre.

Compared with many other hill districts in Scotland, where the stocking amounts to 2 acres per sheep and upwards, the East Border stocking is relatively high. It should, of course, be remembered that the grazings are very accessible, rock exposures are few, and wet ground is almost entirely absent.

The high percentage of lambs on East Border hill farms is worthy of note. This subject will be referred to later.

Effect of Herding.

On an average of 30 hirsels in the area, the number of sheep per hirsel works out at 28 score and 8, or 568 sheep. This represents the number of

sheep under the control of one shepherd. The average area of these 30 hirsels is 678 acres. The hirsel is usually divided into two or three hefts for convenience in herding and management, and care is taken that the land on each heft covers as great a variety of soil and herbage as possible. Inequalities in this respect are unavoidable, however, and so certain hefts are more addicted to pining than others. In the same way, different hirsels are more subject to the malady than others.

The sheep on each heft are confined to this particular area of ground, though not necessarily by fencing. It follows from the foregoing that they will have a free run of anything from about 200 to 300 acres. It will be realised, therefore, that the actual composition of the diet of hill sheep is not easy to arrive at. Information obtained by ordinary methods of sampling either the soil or the herbage may be liable to considerable error.

A cardinal principle in flock management on pining land is that the herding must be thorough and efficient. The sheep must be taken off the tops each morning and set out into the deeper land and made to travel to the furthest limits of the grazing. In the afternoon, the natural instinct of the sheep is to work back and ascend to the highest parts before nightfall. In cases where the deep ground is at the top and the pining ground is low down, the

sheep must likewise be kept regularly on the move. The sheep will not rake the ground by themselves, however often they do it, but must be constantly kept at it.

It is ocassionally the practice on pining farms not to have the grazing divided into hefts but to give the sheep the run of the whole hirsel. This increases the tract of ground available and thereby ensures a better range of herbage and more exercise. This system is reported to be of special value where pining is severe.

Exercise is essential and an amount of dogging that would be considered injurious to sheep in ordinary practice is held to be beneficial on such land. Farmers believe that the bodily functions are kept in better order, and that plenty of exercise tends to keep pining away.

An example of what may happen when sheep are left to themselves for any length of time without herding was quoted to the writer. During the hay season, the shepherds on a pining farm were withdrawn from their normal duties to assist in securing the crop. This was done for reasons of economy and also owing to the scarcity of casual labour. Within a few days, an outbreak of pining had begun, and when herding was resumed a considerable number of ewes and lambs had to be sent off the farm for treatment. The sheep had settled on the pining portions of the grazing, leaving the deeper ground untouched.

Breeding Management.

On many of the higher places in Bowmont Water and Kale Water where pining is prevalent, it is a regular practice to wait until Cheviot ewes are three years old before taking a crop of lambs. No lambs are taken off gimmers. If gimmers are bred from, it is found that it interferes with their normal development and tends to favour pining. Gimmers' lambs are not so well nursed, there is a high percentage of small secondary lambs, and the value of the draft ewe is depreciated. It pays, therefore, to sell 3 crop ewes at 5 years old instead of 4 crop at this age, as is the custom in better districts. The practice is dictated by the character of the land. It is unable to give the required growth and bone development if stock are mated too early.

The general practice on pining farms in the area is to winter the ewe hoggs at home. They are changed off the farm for a month or thereby in August and again in February, so that it is not home wintering in the ordinary sense. Out of 26 pining farms from which particulars were obtained, 20 followed the above system, while 6 sent away the hoggs altogether. As far as pining is concerned, it would be an advantage to have the hoggs away on suitable ground the whole winter. The total cost amounts to about 10/- per head and represents a sound investment.

Beneficial Effects of Changing.

On pining farms sheep cannot be kept for any considerable period at a stretch otherwise they begin to do badly and develop the disease. It is a remarkable feature that the disease can be prevented to a considerable extent by regular changes to a different soil type. The soils to which the sheep go are generally situated on the Old Red Sandstone or on the Carboniferous formations, commonly referred to as Freestone or Limestone, respectively. Beneficial changes are also made to Silurian and even to the better types of Andesite itself. The soil is the deciding factor.

The farms or grazing areas which are chosen for changing are often at no great distance away. In some cases a neighbouring farm, if outside the pining belt, is sufficient to work the desired effect. Some farmers rent grass parks in low-ground areas specially for the purpose, while in a number of instances the farmer runs a low-ground farm as well as a hill farm. The essential point is that the soil be of better quality than that on which the sheep have been stationed. As a rule the change is made to grass but occasionally a winter-change may be made to roots.

Normally two changes per year are regarded as necessary where pining is severe. These periods are not adhered to strictly by the calendar but depend to

some extent on the condition of the flock. The first sign of a check occurring in a few individuals is generally taken to indicate that the changing process must be set in motion without delay. The recognised periods are :-

(1) February and March for all classes of sheep.

(2) August and September for Hoggs.

(3) September and October for Ewes.

A change of three weeks duration is usually given to ewes and gimmers. For lambs after weaning and hoggs in spring, a month is considered necessary. Shorter periods are occasionally employed but are not found so beneficial or reliable.

A suitable change has a marked effect on the health and vigour of the animals. Instances are frequently quoted where members of the flock have been so weakened by pining that they have been unable to travel off the ground. Within three weeks, however, they have completely recovered and have been brought back in a vigorous and thriving state.

An essential feature is that all sheep on the farm require to be regularly changed if the disease is to be effectively controlled. It is of little use sending away only those sheep which are visibly affected, as many others may develop symptoms soon after.

Effects of Season.

Contrary to what might be expected, a mild winter often has a debilitating effect on hill sheep in the Borders. This is reflected in a less robust condition at lambing time and a greater tendency to pining. In such a winter the ewes are inclined to keep to the finer and sweeter ground which consequently gets dirty and the animals are more liable to pick up parasites. The disease known as Blood-rot which is occasionally present on some farms has been ascertained by Stewart and Piercy (35) to be due to parasitic worms in the digestive tract. This also occurs on the Scottish side of the Cheviots and has been treated by the writer by dosing with Sulphate of Copper.

On the other hand, a winter in which there are considerable spells of frost and occasional snowfalls tends to put hill sheep in a more thriving state and they come out in fitter condition at lambing time. In hard weather the sheep are compelled to range over the deeper portions of the grazing and thereby obtain a change of fodder on comparatively clean ground. The quality of the feeding on this ground is also better.

The weather during the lambing period itself has an important effect. Hill lambing in the East

Borders begins on the 16th April in the lower districts and towards the end of the month in the higher areas. If the spring is late there is an absence of grass and the ewes and lambs suffer considerably. Special notes were made of the weather during two different seasons and these examples may be quoted to show the effects on pining.

In 1936 snow lay continuously on hill land from April 12th to 18th, and on the highest farms until April 25th. There was hard frost on 10 successive nights lasting from April 12th to April 22nd. Ewes lambed in the snow and the frost checked all growth of grass. There were scores of milkless ewes and ewes with bad udders, while the majority of flocks got very run down in condition. The result was the highest incidence of pining among ewes and lambs during the summer that had been experienced for many years.

1937 was characterised by conditions of exceptional severity during the period before lambing. Snow began to fall on February 27th and thereafter there was a succession of heavy snow-storms throughout March, with much drifting. Many ewes were buried in drifts, and damage was done by the pregnant ewes straining themselves in the deep snow. Hill land was not clear of snow until early in April. Owing to the protection of the snow, however, the grass came up green and fresh, and by the middle of April

there was a plentiful supply of young grass. Weather during lambing was exceptionally good with almost an entire absence of frost although there were some cold days in May. Pastures made excellent progress and the net result was that although ewes were much reduced in condition at the opening of the lambing season they recovered considerably and rather less pining than usual was reported during the summer thereafter. It will be seen, therefore, that there is a difference in the amount of pining in different years.

Pining often worse in a wet summer.

It is the experience of the majority of farmers that pining tends to be worse in a wet summer and less prevalent in a dry summer. It might be thought that the position would be reversed, as it has been shown from investigations on the composition of hill pasture that the mineral content is poorer in a dry season (36). As a rule, however, this has only an indirect bearing on the question. The explanation is that in a dry season the sheep are better spread over the grazing while in a wet season the deep-land herbage grows too strong and the sheep are more inclined to settle on the shallower and sweeter ground.

Where the amount of deep land is very limited, however, a dry summer may cause a definite shortage of keep and in that case there is a greater tendency

to pining, as might be expected. Much depends upon the farm itself.

The Influence of Cattle.

The East Borders in common with most hill districts carries only a limited number of cattle on hill grazings. Where there is a proportion of arable land on the farm there are greater facilities for winter feeding and a bigger stock of breeding cattle can be run than on purely hill farms. In the course of the survey, a representative group of farms was taken and particulars obtained regarding the number of cattle grazed on hill land in the summer of 1935. The group represents a fair sample of the area and includes pining and non-pining farms. Particulars are shown in the following statement.

Cattle summered on East Border Hill Land, 1935.

No. of Farms	22
Acreage of Hill Land	28,143 acres
No. of Breeding Cows	166
No. of Calves	158
No. of Bulls, Bullocks and Heifers	263

No. of acres per Breeding Cow	169.5
No. of acres per head of Cattle Stock	47.9

Detailed particulars of each farm are given in Appendix (2) on page 247.

From the figures it will be seen that the stock of cattle works out, on the average, at 1 breeding cow to 169.5 acres; or 1 head of cattle, including young calves, to 47.9 acres. Galloway cows formed the principal stock, but on the lower places cross-Shorthorn cows were frequent.

It is little use coming to any conclusion regarding this relatively low rate of stocking with cattle without first taking into account the peculiarities of the area. In most sheep farming districts the difficulty in keeping cattle is the problem of winter keep. In the East Borders, however, the problem is often one of summer as well as of winter keep. The rainfall is comparatively light, the soils are shallow, and much of the hill land is liable to burn in a dry season. The deep land is regarded as a necessary provision for times of drought as well as for winter use. In a dry summer with any appreciable stock of cattle on these hills, ewes and lambs may suffer considerably, and, in addition, may be deprived of their normal reserve of winter fodder. The tendency on some of the drier farms in Bowmont Water and Kale Water is that pine disease may increase in certain years following upon the influence of cattle.

Cattle increase the labour of shepherds who are already working to full capacity. More hay requires to be cut, and on purely hill farms the

facilities are limited. Cattle break down open drains in the bottom land as was found at Boghall by Wilson (37).

An increase in cattle, therefore, requires to be carefully considered in relation to the farm itself. Cattle improve the herbage but an undue number is to be guarded against. The farmer tries to keep on the safe side with the advantage in favour of sheep and in some cases probably an undue margin of safety is allowed.

Effect of Manuring Hill Pasture.

On only three farms in the whole of the East Borders has any manuring been carried out on hill pastures, namely, at Morebattle Lofts, Woodside, and Stotfield. The most notable instance occurred at Stotfield. The late Mr. F. S. Oliver of Edgerston manured 537 acres of Stotfield Hill in 1927, the dressing applied being 8 cwts. per acre of Potassic Mineral Phosphate. This had a marked effect in increasing White Clover, and the results are still visible. Cattle were run in considerable numbers on this hill and greatly helped to improve rough areas infested with Nardus. The late Mr. R. M. Tait who supervised the work stated to the writer that the manuring was beneficial to the health and condition of the sheep and was reflected in an increase in the lamb crop. The manuring, he said, also largely

abolished pining.

Following upon the work at Stotfield, Mr. T. Richardson, then tenant of Woodside, manured considerable stretches of hill land there with 5 cwts. per acre of Ground Mineral Phosphate. No Potash was used. This had a notable effect in bringing up clover and improving the feeding quality of the grazing. Mr. Richardson states that the manuring prevented any tendency to pining in the stock.

Hill land at Morebattle Tofts was manured some years ago with Phosphate and Potash. On account of the dry conditions, the manuring employed was 3 cwts. Superphosphate and 3 cwts. Kainit, per acre. The late Mr. J. Roberton informed the writer that the treatment was thoroughly successful and had a marked effect in keeping off pine.

These are three examples from the area which give evidence to show that the application of mineral manures, and particularly Phosphate, has an influence in preventing or reducing pine. Improvements on similar lines could undoubtedly be made on many farms in the locality.

Effect of Winter Feeding.

The general question whether to feed hay to hill ewes in winter is much debated. No finality is ever reached because the conditions vary so greatly. In the East Borders it is a recognised practice to

provide hay for the stock, because if the ewes get reduced in condition pining is more prevalent. In the severe snow storm of 1937 those farmers who did not use hay had fairly heavy losses from pining thereafter.

The feeding of hay has no bad consequences in the East Borders if used judiciously. The ewes do well on the fine leafy herbage in the following summer and rear their lambs well. In fact, hill ewes on some farms actually go on to roots for a spell in late winter. It is a different matter in rough country such as in the Western Cheviots. Haying in winter in this locality tends to put the sheep off their normal beats and they are not so good at seeking out the finer grasses in the pasture in summer, which in any case are comparatively scarce. In such districts the feeding of hay, except in times of dire necessity, is a mistake, and may result in poorer returns from the lamb crop.

The feeding of rock salt is largely practised but, while of benefit to the stock, is found to have no specific effect against pining. Proprietary mineral licks have been tried in recent years but have not found much favour. Of 15 farmers who used them, only 3 stated that they had found any appreciable benefit against pining. The remainder had various practical objections which they considered outweighed any advantage.

9. CONDITIONS DETERMINING THE VALUE OF CHANGING-LAND.

Reference has already been made to the beneficial effects that generally follow the regular changing of the flock for three or four weeks to a different soil type. This constitutes the standard method for preventing pine in practice. Farms or lands which may be used for changing, however, are found to differ greatly in their value for the purpose. Some indeed may have little or no preventive value. They can roughly be divided into three classes :-

(A) Farms that will cure pining sheep, and that will prevent the disease occurring after the sheep return to their own grazings.

(B) Farms that have no curative value but will prevent pining.

(C) Farms that will neither cure pining nor prevent it. These farms really belong to the pining category.

The value of different farms or lands in preventing pine mainly depends on the character and quality of the soil, and the subject is best considered from that point of view.

A. First-class Changing Land.

On many of the grazings in this category the sheep may visibly respond to the change while on the

ground. On the other hand, they may show no benefit, particularly if the herbage is in a less suitable condition than that to which they have been accustomed. The sheep may actually return in a leaner state than when they went away. Nevertheless, they immediately begin to go forward and soon improve beyond recognition. Farmers usually look for the main benefit of a change from the way the sheep go ahead after they return.

Among Class (A) farms may be put, first of all, most of the heavier types of soil such as clays, together with medium soils containing a good proportion of clay or silt. The heavier the soil the better it is considered to be. A clay soil on Freestone is regarded as specially effective. Heavy land derived from Limestone or from the finer-textured Andesites is also good.

The high value placed upon clay is in line with the theory that pining is due to a form of mineral deficiency. It has been shown that clay and silt are the fractions of the mineral part of the soil which are richest in the mineral elements required for the nutrition of crops and live-stock. Russel (38) has indicated that this is particularly true of certain English soils of a highly weathered type. Hendrick (39) working on North Scottish soils of a relatively unweathered type derived from granite, found that there were certain differences

from the English soils. The majority of constituents, however, and particularly phosphoric acid and iron, were also present in greater quantity in the finer fractions. Regarding the availability of these minerals, Robinson (40) states that the clay fraction usually contains most of the chemically reactive colloidal inorganic material of the soil. This is well borne out in practice.

Robinson (41) alludes to the fact that under conditions where the entrance of air into the soil is impeded, processes of reduction are prevalent. Ferric compounds are reduced to the more soluble ferrous state. This point is alluded to by Aston (42) in connection with the occurrence of Bush Sickness in New Zealand. It may be that trace elements associated with iron are also made more available, as well as some other of the major elements. This condition regarding the exclusion of air is present to a great extent on clay land, particularly if it has long remained undisturbed by cultivation.

The superior feeding-quality of produce derived from clay is so well-known in practice that the matter need not further be commented on. A change from light pining soils which are all poor in clay, to clay-land is held in the highest repute of any change available in the locality.

Peat Soils with Heather and Draw Moss, etc.

Peat soils of a suitable type and producing Heather, Draw Moss, etc., may also be placed in the first class for changing purposes.

There are various qualities of peat, some being comparatively rich in mineral material while others are relatively poor. The method of formation largely determines the mineral content. Waksman and Stevens, quoted by Robinson (43), found Low-Moor peat to contain 10 - 25 per cent of ash in the dry matter. In the case of High-Moor peat, the same authors found only 1 - 2.2 per cent of ash.

Low-Moor peat is usually formed in depressions under water-logged conditions, where silt, mud and flush water are washed in, thereby incorporating much mineral material with the peat. Under Scottish conditions, these are often of an acid type (44). High-Moor peat, on the other hand, is formed when the peat rises above the water table and the resulting vegetation is mainly produced from the decayed vegetation of former years. The composition becomes progressively poorer.

Climatic-Moor is the term given by Fraser (45) to the type of peat formation that develops in mountainous regions, as in Scotland, on the surface of mineral soil due to humid conditions. This peat also tends to develop towards the High-Moor formation. Climatic peat is shown by Fraser (46) often to have

a considerable content of ash, sometimes as high as 22 per cent.

Peat, therefore, is of very varied composition. The availability of the mineral compounds is likewise variable, and depends on such factors as aeration, decomposition, base status, leaching, etc., as described by Fraser (47). Practical opinion, however, is unanimous in ascribing high feeding properties to herbage of a non-gramineous type growing on most peat areas. Farmers find that it serves to balance up the feeding obtained from grassy vegetation growing on mineral soil. Both classes of herbage on a hirsel or heft tend to make a first-class grazing. The subject has not yet been fully worked out on the technical side for any particular area.

In the Cheviot region, most of the main types of peat are represented. In the pining area itself, however, it is mainly restricted to shallow Climatic peat associated with Molinia, and the thin layer that occurs under grass at high elevations. Isolated patches produce heather, etc., as already alluded to, but their acreage is usually extremely small. In close proximity to the pining belt, on the other hand, there are large areas of various classes of peat. These produce Heather, Draw Moss, and associated plants. The significance of peat in the present connection lies in its production of this class of herbage.

Heather (Calluna vulgaris) has been shown by Lauder and Comrie (48) to provide a valuable source of Protein to hill sheep and also appreciable quantities of mineral matter, particularly lime. Thomas (49) working on well-managed heather on shallow peat overlying sandy clay, in Northumberland, also found a comparatively high content of lime. Draw Moss (Eriophorum) was found by Thomas (50) to be particularly high in phosphoric acid in the early spring, in the scallions, but very poor in lime. The mineral content of these plants, in addition to the Protein, is one of their great assets.

Practical opinion places the highest value on the class of heather that grows on comparatively deep peat, at least one foot in depth. Heather that grows on a shallow peaty soil, or on lea, seldom attains such vigour. The annual growth of shoots is small, and the feeding value is found to be poorer. Certain classes of lea heather growing on Freestone soil, or on soils of a clayey nature, are, however, of value in curing and preventing pine and require to be included in the same category as heather growing on peat.

It should be noted that the precise chemical differences in the composition of heather from different soil types still awaits determination.

A change to heather on comparatively deep peat is in high repute, either in autumn when the

new growth is in a succulent state, or in early spring. It is specially so if the pining farm has no heather at all. Cheviot sheep are not well adapted to this class of fodder by itself and may show no improvement while on it. Nevertheless, when returned to their own grazings they make very satisfactory progress.

B. Second-class Changing Land.

Grazings or arable land in this class are only effective for changing purposes provided there is no pining among the stock when they go there. If there is any pining about them they may begin to develop the disease when returned to their own grazings. Owing to the demand for changing-land, a farmer is not always able to get the type of grazing he wants and may therefore have to utilise this class.

Light sandy or gravelly soils in poor condition may usually be placed in this category, irrespective of geological formation. These soils are comparatively low in clay and humus, short of lime, and are low in available minerals. Such soils if under a grassy vegetation are of limited use for changing. This does not apply to heather, however. Heather on soils of this type is often of considerable value.

An instance in which a grass-change to soil of this type did not cure pining among hoggs came

under the observation of the writer. In the autumn of 1936, 132 ewe hoggs were changed off pining land to grass fields situated on the Old Red Sandstone formation. Pining was already apparent among a few individuals. The fields were in a comparatively poor condition and the soil was fairly light in texture. The hoggs were away for one month. Shortly after their return, pining broke out, and within three weeks a total of 13 per cent had become affected. They were given mineral feeding, after which recovery took place. The land had not been strong enough and the herbage had been unable to control pining.

C. Pining Land.

In practice, cases occur where sheep are changed from one pining farm to another. This produces beneficial effects of a temporary nature. Like all changes, it acts as a stimulus. If the progress of the sheep has been inclined to hang fire, it gives them a help forward. If there is any pine about them, however, it will not cure it. If they are healthy, it will not ultimately prevent it.

Similarly, putting sheep on to roots on pining land is not found altogether to eliminate the trouble. Arable land on pining farms is, as a rule, limited in acreage and is therefore often worked on a short rotation. Only a moderate application of

manures is usually given. The condition of the crops produced is therefore poor as far as feeding value is concerned.

Apart from land in the recognised pining belt, there are certain areas of land of poor quality on neighbouring formations which behave in a similar manner. These also are neither of curative nor of preventive value when stock are changed on to them. This again raises the question that pining is not confined to the Andesite formation but may be found in localised areas in other districts.

While heather on deep peat and on Freestone, etc., gives all the advantages required for changing, heather on the usual type of shallow Andesite soil is not satisfactory. In places where it is found in quantity it frequently has an influence in helping to keep the trouble within bounds, but cannot be relied upon. Pining is found in these places in spite of heather.

Deduction.

It will be realised from the questions discussed in the preceeding paragraphs of section 9. that pining can be controlled by regular changing to a type of soil and herbage which is better supplied with available mineral matter than that to which the sheep have been accustomed. The high value placed upon heather which grows on peat still, indeed,

leaves room for technical enquiry before a full explanation of its status can be arrived at. What seems clear, however, is that an improvement in the general mineral content of the ration of hill sheep confers resistance against pining. The disposition to pining is rendered more acute if the general mineral standard is deficient.

Changing practice is liable to modification.

While the system of changing the flock twice a year holds good where pining is severe, the practice is liable to modification according to circumstances. Where pining is not unduly severe, only one annual change may be given. Hoggs, for example, may be supplied with concentrates and hay in late winter instead of the usual change at this time. In other cases, where pining is of a very mild type, it is only considered necessary to have two changes in the life-time of the stock, namely, once as hoggs and once as gimmers or ewes.

Some farms consist of non-pining land as well as of pining land. Where there is a substantial acreage of arable land or enclosed grass of this type, the required change can regularly be given within the farm itself, without sending the sheep elsewhere.

Differences in stock in their response to changing.

Different classes of sheep may, in practice, respond differently on pastures to which they are sent. Enclosed pastures in low-ground districts are often in a rough state in autumn, particularly if the season has been such as to produce a heavy growth of grass. Grazing of this type is not at all suitable for hoggs, which do best on comparatively short and leafy herbage. It is mainly a question of fibre. A high content of fibre in the food of young sheep makes the feeding unsuitable. Ewes, on the other hand, can make headway on a more fibrous type of herbage. They have also acquired the faculty of selecting their grazing to a much greater extent than hoggs and consequently can make better use of the grazing.

It may here be mentioned that this principle is utilised in the East Borders in allocating the stocking of different hefts or hirsels. The rougher grazings are often set apart for ewes, and the hefts with more fine ground may be used for hoggs and gimmers. This again is liable to modification as the rougher grazings are not so good for the young lambs running with the ewes.

An instance showing the differential effects of changing was observed in the autumn of 1936. The same fields were utilised by a farmer for changing both ewes and hoggs. There was too much grass

on the fields owing to inadequate stocking during the summer. The ewes improved considerably on the ground and went ahead on their return. The hoggs, however, did not make satisfactory progress and showed only limited benefit thereafter from the change. It is necessary, therefore, to consider the nature of the grazing as well as the quality of the soil when selecting pastures for a change.

Sheep Worms.

Were the cause of pining mainly connected with the prevalence of stomach and intestinal worms as suggested by Stewart and Piercy (51), farmers would require to take great care to send their sheep to clean pastures or to pastures that had carried comparatively light stocks in previous months. This is not so in practice, however. Clean pastures have advantages, but the sheep have usually to be changed on to grazings that have previously carried many stocks and where no special cleaning of the ground can be given beforehand. The benefits from such changes are well marked. Old pastures that are presumably fairly heavily infected with parasites are found to answer well. So long as the soil is of the right type and the herbage is in a suitable condition for sheep, good results usually follow.

The subject of parasitic infestation has already been referred to on page 50.

It is true that the changing system usually benefits the home grazing. In most cases no fresh stock come up to replace those sent away. The pastures therefore get a chance to clean and the grass freshens up by the time the flock returns. This undoubtedly is one benefit of changing but it is obviously due to other factors besides the question of parasites.

The Cost of Changing.

While the practice of changing is usually successful in keeping the majority of the flock in health, it involves a good deal of expense and inconvenience. Sometimes the type of land required is difficult to get, and prices may be high. On the average, the cost of grazing amounts to between 4d. and 6d. per head per week, depending on the quality of the grazing and the locality. For a total change of six weeks annually, made up of two changes of three weeks each, the charges involved therefore are 2/- to 3/- per head. Transport in some cases may add 6d. per head to this sum for each change. The average cost on eight farms, several of which had only one annual change, amounted in 1936 to 2/8 per head, for the year. This represents an annual charge of £133 for a stock of 1,000 ewes and hoggs.

10. TREATMENT OF PINING SHEEP IN PRACTICE.

The farmer in the past has concentrated his efforts on methods of prevention, and the system of changing the flock has been evolved as a practical solution. There is no corresponding system of curing the disease once it has arisen, apart from sending the affected sheep away. The farmer has to do his best in the circumstances. When it does break out, therefore, farmers regard it as the worst disease affecting sheep in the area. On the one hand, it is liable to affect ewes at the nursing stage and so give a severe set-back to young lambs. On the other hand, it may break out amongst lambs at the time of the Autumn sales and disorganise the marketing arrangements.

Early recognition of the disease and prompt treatment are everywhere regarded as of first importance if pining animals are to be dealt with successfully. The longer the delay the more does the disease sap the vitality and produce a moribund condition which is almost hopeless to treat by ordinary methods used by farmers in the past. Should such an animal ultimately recover, its value is so depreciated as to be worthless as a member of the flock.

The value of concentrated foods produced elsewhere than on pining land is well known in prevention. Practically all farmers agree that any

"box feeding" will prevent pining if given for an extended period. Such foods as Bran, Dried Beet Pulp, Brewers' Grains, Oats, and Maize, are in high repute. Linseed Cake is considered to be best of all. No doubt cakes in general are in this category partly on account of their protein content. There are cases, however, where feeding with Maize has not entirely prevented pining, and the impression has been formed by the writer that this particular food is not always reliable.

Just as concentrated foods will usually prevent pining, so they are effective as a cure if given in time. A pining sheep, if put on to concentrates in the early stages, will show recovery in three or four weeks. The great difficulty regarding the question of concentrates, however, is that it is impracticable on the majority of hill farms to use them either to hoggs or ewes in ordinary practice. When such sheep begin to pine, therefore, they have never been accustomed to eat out of a box and so cannot be made to take this form of feeding however much they may require it. To teach them may take many weeks, and by that time they will bw far gone in pining. The method is only open to those whose sheep have been accustomed to the use of concentrates at some previous period. This also applies to the putting of pining sheep on to roots. Unless they have previously been accustomed to roots, it takes a

considerable time before they will begin to eat them.

In the majority of cases, therefore, the farmer has to rely on grass as a cure. If heather of a suitable type is available in the neighbourhood, this also may be used.

On some farms there are enclosures with a better quality of soil than the hill land on which pining sheep will tend to mend if drawn out in time. Clay land is of the greatest value. Clay on Andesite is good. On one pining farm on the Andesite with seven enclosures, the only one that is known to have any value in turning piners consists of a loamy soil with a clay subsoil and is situated at a lower elevation. This enclosure is largely used for the purpose, but is mainly effective in the early stages. The other enclosures are also used but concentrates require to be fed otherwise they are quite useless.

Where there is no land of a suitable nature on the farm, and where there is no hope of getting affected sheep to eat concentrated food, the pining animals require to be sent away. On suitable pasture or grazings they make a good recovery.

On some hill farms, however, any sheep that develop pine between changes are merely left to take their chance.. The lambs are taken off them, if they are at the nursing stage, and in the course of time a proportion of them may begin to improve. The majority, however, go downhill and ultimately succumb.

Care requires to be exercised in all cases where pining sheep, or any other sheep, are changed off the hill on to rotation grass, especially in early summer. The flush of grass is apt to cause digestive disturbances and there may be a considerable death rate if the change is made suddenly. In the same way, the feeding of concentrates requires to be introduced gradually until the sheep have become accustomed to the new diet.

The time required to effect a cure of pining in practice is about three to four weeks, if taken in the early stages. If treatment is delayed, however, three or four months may be required.

11. THE INFLUENCE OF PINE IN THE EAST BORDERS ON OTHER DISEASES.

Apart from pining, the East Borders are relatively free from serious outbreaks of disease. Indeed, several diseases which are common in neighbouring areas are almost entirely absent. The comparatively dry climate and free-draining soil tend to make the conditions healthy in many respects for sheep. There is the further advantage that under these conditions it is possible to secure hay in reasonably good order in most seasons for winter feeding. It is also well established that the changing of the ewes in autumn acts as a stimulus which often proves of value during the mating season. These factors all tend to promote a fairly high rate of fertility. Added to this is the fact previously mentioned that on several farms gimmers are not bred from, and so the production rate in respect of ewes actually tupped is improved. This fact requires to be borne in mind in considering average production figures for the area.

Broadly speaking, under conditions of management in the area, the pining tendency does not have a marked effect in favouring the occurrence of other diseases. There are one or two exceptions which are pointed out later.

The Lamb Crop in the East Borders.

Practice varies in regard to the number of crops of lambs taken from hill ewes in the area. In the survey made of 26 farms during 1935, it was found that 5 crops of lambs were taken on 6 farms, 4 crops were taken on 14 farms, 3 crops were taken on 5 farms, while one farm ran a flying flock of cast ewes. 5 crops are normally taken off Blackface stocks and 4 crops off Cheviots. Those farms where 3 crops are taken mainly represent Cheviot stocks in which gimmers are not bred from.

The percentage of lambs reared per ewe is high. The survey on 26 farms during 1935, which was quite a normal year, showed that out of 17,638 breeding ewes, comprising hill stocks, the crop of lambs was 92.38 per cent (page 75). This was the percentage arrived at when counts were made by farmers at cutting time, and excludes losses among lambs during the first few weeks of life. The actual percentage of births, therefore, would be represented by a higher figure. 4,329 of the above ewes were located on farms where gimmers are not put to the tup, and therefore these ewes do not include gimmers.

Regarding the actual birth-rate, figures are difficult to arrive at, as counts are not always made at lambing time. One farmer, however, who herds one of his own hirsels, kindly supplied information in respect of his total breeding stock of 800 Cheviot

ewes and gimmers. Gimmers were bred from in this instance. Particulars of births on this farm are shown in tabular form for each of three years, together with the corresponding number of lambs at cutting time.

	Ewes.	Lambs dropped.	Lambs at cutting time.	Lambs at cutting. per 100 ewes
	No.	No.	No.	
1935	800	908	758	94.7
1934	800	849	779	97.3
1933	800	860	759	94.8

The farm is situated at an elevation of 750 feet, rising to 980 feet, and is much addicted to pining. Regular changes of the flock, however, are made twice yearly.

In a Cheviot flock of 760 ewes running on moderately pining land at an elevation of 1100 feet, rising to 1400 feet, 60 ewes were without lambs in 1936, while 16 ewes had twins. These figures are fairly typical of the farm in question.

There must be few hill districts which can show a higher percentage of lambs than the East Borders, where the average count at cutting has been shown to exceed 90 per cent. Losses between cutting and weaning are as a rule only slight. Representative figures are difficult to obtain for other parts of Scotland. Certain eastern districts such as the Lammermuir country would no doubt equal or even

exceed this percentage. In some western areas, on the other hand, as in parts of Argyllshire (52), the number of lambs reared may not exceed 50 per cent of the ewe stock.

The Occurrence of Other Diseases.

During the survey, an enquiry was made on pining farms in the East Borders into the occurrence of sheep diseases, in addition to pine. The average results of this enquiry are shown in the table following and are referred to in succeeding paragraphs. They are average figures for the two years 1934 and 1935. In those years the feeding of mineral mixtures, apart from the occasional use of proprietary mineral licks, was as yet unknown in the area, and the figures, therefore, are not influenced by this factor. Complete data could only be obtained from 12 pining farms as several farmers did not care about disclosing full particulars. Partial data, however, relating to particular diseases was obtained from some of these farmers and this is included where reference is made in the text.

In all cases, the information was got by personal interview with the stock-owner. In most instances, they were good enough to consult their record books for precise figures. These figures, therefore, in so far as they refer to such matters as the total death-rate in ewes and hoggs, and

lambing returns, are of considerable accuracy. When it comes to the allocation of deaths and pathological conditions under different heads the information is less accurate. The figures are as near as can be got for any area and will serve to give a general impression of the commoner diseases occurring in the district.

Average Annual Incidence of Death and Disease on 12 Pining Farms in the East Borders.

Average of the two years, 1934 and 1935.

Total Stock - 11,634 Ewes, Gimmers,+ Hoggs.

Total Death Rate.		
Ewes and Gimmers	3.12	per cent.
Hoggs	4.01	per cent.
Death from Pine. (excluding lambs)	.34	per cent.
Pined Sheep. (excluding lambs)	2.27	"
Tup Eild Ewes.	4.01	"
Abortion.	2.78	"
Braxy in Hoggs.	2.22	"
Lamb Dysentery. (per 100 ewes)	.88	"
Grass Sickness in Lambs. (per 100 ewes)	1.15	"
Liver Fluke. (Deaths)	.16	"
Louping Ill.	-	-

Death Rate.

The average annual death rate in ewes and gimmers for the two years 1934 and 1935 was 3.12 per cent. On 22 farms, including those in the above table, the figure was 2.47 per cent. These figures bear out the fact that the district, although pining, does not have a high death rate. In parts of west Scotland, a death rate in ewes of around 10 per cent is not uncommon (52).

The same remarks apply to hoggs. The average annual death rate was 4.01 per cent. Hoggs were wintered at home in 10 out of the 12 farms but were changed in autumn for three weeks or thereby in all cases. The comparative healthiness of the grazings in winter for hoggs no doubt largely accounts for the practice of home-wintering.

Pining.

Deaths from pine are small. The protracted course of the disease usually allows an opportunity to give treatment with some success.

The incidence of pining has already been discussed (page 54). The figure of 2.27 per cent given in the above table relates to the whole flock (excluding lambs). The figure of 3.0 per cent stated previously on page 54 refers to the ewe stock only. The practice of changing hoggs immediately after weaning is so well established that compara-

tively few hoggs become affected.

Tup-Eild Ewes.

Tup-eild ewes represent one of the chief sources of loss, the figure being 4.01 per cent. It is generally distributed on all farms. To some extent it is counteracted by the changing of the ewe stock in autumn and thereby promoting an improvement in bodily condition when the tups go out in November. Such a long period often elapses, however, between the change and the commencement of tupping that the beneficial effects on fertility may have largely disappeared. On the farm with the highest incidence, namely 13 per cent, which is much higher than the average, the ewes were changed in August for only two weeks. The effect would in this case be largely lost by tupping time.

It seems clear that pine disease may often tend to have a more or less direct influence in giving a fairly high proportion of tup-eild ewes. The somewhat lower state of vitality of the stock, particularly in severe weather at tupping time, would naturally have this effect.

Abortion.

Shepherds have sometimes stated during the enquiry that there is more abortion on pining places, particularly if a check is received about two months

after pregnancy. One or two shepherds stated that ewes which abort early may be reported as tup eild. It is probable that there is some truth in this but how much is impossible to say.

This question apart, one would have expected to find a fairly clear correlation between abortion and pining. The figures for the two years under review, however, do not show a high incidence of the trouble. On 7 farms the regular practice of changing the ewes in February or March was carried out, and this no doubt was beneficial in the latter stages of pregnancy. The highest individual loss was 5 per cent.

Braxy.

An outstanding feature disclosed by the survey is the definite connection between pine disease and the incidence of braxy. Braxy is largely absent from the area. Out of 16 farms with 2,862 ewe hoggs, which were all wintered at home after the usual change in August or September, the average loss was only 61 hoggs, or 2.13 per cent. No vaccination or other preventive treatment was practised. There was no braxy at all on 6 of these farms, and the highest loss at any farm was 5 per cent. Several farmers who did not give precise figures stated that their losses were very small.

This is an example of a disease which is of

little or no consequence on the majority of pining farms, while it is present to a considerable extent in neighbouring districts at a similar altitude. The explanation would appear to be that the stock on pining land are not as a rule in that progressively thriving state which favours braxy. Bleeding was practised in olden days in some Border districts and no doubt the tendency to anaemia acts in the present case in a somewhat similar manner.

Lamb Dysentery.

Lamb Dysentery is common in many Border districts but at the time of the survey in the East Borders only 10 out of 20 farms reported losses. In one case the loss of lambs, reckoned on the ewe stock, amounted to 5 per cent. Farmers are fully alive to this insidious disease, and preventive measures are fairly widely employed. Control by vaccination of the ewes or inoculation of the lambs, however, is the exception rather than the rule. On only 3 farms was this method practised, while on 9 farms the administration of Lamb Dysentery Powders was in regular use, apparently with success. These are proprietary compounds and are held in high repute. They are believed to suit certain farms, while in other cases only vaccination or inoculation are successful.

There appears to be no direct correlation between this disease and pining. The fact that stock

run fairly thickly on the grazings might be presumed to favour it.

Grass Sickness in Lambs.

This is an entero-toxaemia which generally affects some of the best lambs from about three to eight weeks old. It is also known as pulpy kidney disease. Male lambs are most subject. Lambs off older ewes are mostly affected as they get more milk. It is most prevalent in seasons in which the grass comes early, providing flush conditions of herbage to the young animal. The germs are believed to be normal inhabitants of the intestinal tract but only when certain favourable conditions for their development are set up do they multiply and prove fatal. It will be seen from the table on page 110 that this disease was responsible for slightly heavier losses than Lamb Dysentery. It was present on all farms in addition to the 12 farms where special enquiry was made. A check to the animal appears to be helpful in preventing the onset of the disease. Some farmers, therefore, cut and dock their lambs as soon as an outbreak occurs, and this helps to stop further losses.

The disease is allied to Lamb Dysentery, the causal organism being reputed to be a strain of B. welchii (53 and 54). Those farmers who have vaccinated or inoculated against Lamb Dysentery find that

the lambs are rendered less liable thereafter to grass sickness. This does not, however, entirely prevent it.

Whether lambs on pining land are more liable or less liable to grass sickness than lambs on non-pining places is a matter that would require data from both types of places for an answer. Recent work in New Zealand (55) suggests that there is some correlation between the nutritional status of the ewe at lambing and the susceptibility of the lamb in early life. In New Zealand, however, the disease appears to be most prevalent in slow-thriving lambs, while docking and castration tend to precipitate the disease. This is quite contrary to experience in the Cheviots, and seems to show that the disease there probably takes a different form. The matter must remain for the present undetermined.

Liver Fluke.

Losses from Liver Fluke are negligible. Only two farms showed any large number of cases, the greatest loss being 4 per cent of the total stock of ewes and hoggs. 12 out of 19 farms reported no losses, either in 1934 or 1935. The disease is confined to areas of wet land. The dry conditions in the region as a whole largely rule out this particular disease.

Louping Ill or Trembling.

This is a virus disease affecting the central nervous system of sheep and is carried by the Sheep Tick (Ixodes ricinus). Out of 28 farms in the pining belt, only two reported the presence of this disease and that only in a very slight degree, causing an occasional death. Tick-borne fever is unknown. Ticks were observed by the writer in one of the above instances. On 4 other farms out of the 28, ticks were reported to be present to a very slight extent on certain parts of the grazings but they do not give rise to louping ill or tick-borne fever. In these cases the ticks are presumably free from infection.

The conditions in the East Borders do not appear to be favourable to the development of ticks, although they are present in large numbers in the Western Cheviots and on farms not far distant from the pining area, causing heavy losses. Losses of from 5 - 10 per cent from louping ill occur on one farm just bordering on the pining belt. In view of the constant changing of sheep, infection could hardly fail to become widespread were there not certain factors unfavourable to these organisms. The pining tendency in the sheep is, by itself, unlikely to have any deterrent influence - rather the reverse, for ticks are numerous in some of the poorest hill districts in the Borders. On the other hand, the soil conditions on pining land probably present

limiting factors to their establishment. Cameron (56) has pointed out that where the ground is dry and well-drained, the tick will fail to become established even when it is repeatedly introduced. He further states that it flourishes on damp, ill-drained hill pastures with an acid soil and covered with a rank growth of grasses. Farmers find that old rough heather also encourages them. These conditions are much less prevalent in the East Borders than elsewhere.

It may be concluded, therefore, that the absence of ticks and louping ill may be definitely correlated with the nature of the pining area itself. In other words, the conditions of soil and herbage on the Andesite formation, on the Scottish side at any rate, are unfavourable to the establishment of the tick pest. It is of interest to note that in other parts of the Borders where particular farms are affected with pining, it has been found that louping ill is often absent.

Lung Worm.

This is present on a few farms but to what extent was not ascertained in the survey. The symptoms resemble pine in some respects but differ from pine in that the gait is stiff and stilted, the back is often slightly arched, scour is more or less present, especially in hoggs, and the breathing is

accelerated. Coughing is not always present. In bad cases, a frothy discharge is seen around the nostrils, and a fetid smell can often be detected at the nostrils.

A severe infestation was observed on two pining farms, both of which had a certain proportion of wet land and, incidentally, had the largest losses from Liver Fluke recorded in the survey. On one of these farms, part of the land is pining and part non-pining, separate flocks being run on each section. The non-pining part has, if anything, the greater amount of wet land. Sheep on the pining land have always shown a greater number of cases of lung worm and more severe symptoms of the disease than those on the non-pining land. The debilitating effects of pining are in this case held to render the stock more subject to lung-worm attack.

Stomach and Intestinal Worms.

This question has already been referred to. There is little doubt that a trace of pining among stock reduces their resistance to these parasites which may therefore contribute to the onset of the malady. The actual part played by worm infestation in the aetiology of pine, however, has probably been exaggerated in the past. It is significant that no farmer in the area considers that worms have any direct connection with the disease.

Pregnancy Toxaemia.

It is commonly stated that this disease is confined to lowland flocks. Ewes carrying twins on hill farms in the East Borders are, however, subject to it, though the percentage of ewes in the twinning category is not high. Several farmers in the district have been aware of this disease for many years. A farmer with a life-long experience of the area stated that most of the losses in ewes before lambing occurred after a severe winter with ewes carrying twins. Since preventive measures against pining were introduced on this farm, losses from this cause have been reduced.

Summary.

It has been shown that under conditions of management on pining land in the East Borders, the productivity of ewes is fairly high compared with some Scottish areas. There is, however, room for improvement. Death among ewes and hoggs is comparatively light.

From the enquiry into the prevalence of various diseases on pining land, there emerges the finding that the incidence of braxy is extremely low, while louping ill is practically non-existent. Both these conditions are directly connected with the aetiology of pining. The relative freedom from braxy is largely due to the rather lower standard of

vitality in flocks on pining land. The absence of louping ill is due to unfavourable ground conditions for the multiplication of the sheep tick.

As regards the debit side of pining, the number of tup-eild ewes tends to increase on pining land, and probably some adverse influence is exerted on the rate of abortion. That this is so is supported by the fact that measures which have been successfully introduced by the writer for the control of pine disease have also been effective in reducing the number of tup-eild and aborted ewes on hill farms in the pining area.

12. GEOLOGY AND SOILS OF THE PINING AREA.

According to Peach and Horne (57) the Southern Uplands of Scotland and the Cheviot Hills form the remnant of an ancient plateau which subsequently became highly denuded and modified by geological intrusion. The plateau consisted originally of a large mass of Silurian rocks of sedimentary origin. This Silurian platform became buried under younger deposits. Throughout the ages, however, these younger deposits have been gradually removed over enormous areas and now expose the original foundation of Silurian rocks in the Lammermuir Hills and the hills of Peebleshire and Selkirkshire.

In the Cheviot Hills, with which we are mainly concerned, the Silurian platform is still largely buried under younger strata. In the East Borders it only comes to the surface in a few irregular patches. One of these occurs at the head of Kale Water, forming most of the hill land of the farms of Upper Hyndhope and Nether Hyndhope. Another occurs to the west of Edgerston by Camptown, Edgerston Rig, and Mervinslaw. A third patch runs from Oxnam in the direction of Crailing. The majority, though not all, of the farms on these tracts of the Silurian formation are free of pining.

The great mass of rock which now overlies the Silurian over the greater extent of the hills of the

East Borders is the Andesite, or, as it was formerly termed, the Porphyrite formation. (58). These rocks represent a great lava sheet which was poured out at the surface during the Lower Old Red Sandstone age. Geike (59) states, "This volcanic pile, consisting mainly of bedded andesites which rest unconformably on the upturned edges of Wenlock shales and grits (Silurian) present a most typical display of the lavas of the Lower Old Red Sandstone". He further states that the thickness probably amounts to several thousand feet.

The Andesites begin in the vicinity of Carter Bar and run eastwards through Yetholm. The total distance is approximately 16 miles, with an average width from the Scottish Border of about 6 miles. The area mainly consists of hill land. All but a small part of the East Borders is, therefore, composed of this formation, and with certain exceptions this also constitutes the pining belt. Portions of the Upper Old Red Sandstone occur among the Andesite at lower elevations but these are of limited extent and are generally pining also.

Immediately to the west of the pining belt lies the Carboniferous formation but this is largely free of pining except in a few localised places.

Glacial Action.

Most of the area shows traces of severe glaciation. No drift maps have, however, been

produced for this part of Scotland by the Ordnance Survey. The hills, particularly at lower elevations, generally present a steep cliff-face to the west or south-west where the pressure of ice has worn them away. Of glacial debris, however, the remains are not always abundant. They often form a shallow covering on some of the lower flats and slopes, and may be found as fairly deep deposits in hollows and along water-courses. The material, however, appears to consist mainly of Andesite drift. Towards the western part of the area where the Upper Old Red Sandstone abutts on the Andesite, traces of sandstone material have been carried eastwards for a mile or two on to the Andesite. This can be seen at Middlesknowes and at Swinside Townhead. Where the Silurian lies adjacent to the Andesite, the land to the east may have had Silurian or other drift superimposed, as at Rennieston, Upper Samieston, and Cleuchside. The soil here is heavy clay and these farms are not pining. On the other hand, the Andesite rock in this locality is much harder and finer in texture, and shows a relatively small proportion of phenocrysts. Rock of this type tends to produce a heavy type of soil.

Taking the area as a whole, the soil over very large sections of the Andesite appears to have arisen directly from the underlying rock. In other parts, it consists to some extent of drift material,

probably mainly derived from Andesite.

Composition of typical Andesites.

Andesites belong to the Intermediate class of extrusive igneous rocks, being neither very acid nor very basic. Geike (58) gives the approximate composition from various centres in the East Borders. Details of the percentage composition are set out in the table below.

	Cocklaw-foot.	Currie-ston.	Duncan's Dubs.	More-battle.	Rennie-ston.	Whitton Hill.
SiO_2	62.29	63.38	59.44	59.82	62.81	60.70
Al_2O_3	17.03	15.77	16.15	16.96	16.40	17.98
Fe_2O_3	.93	.73	1.05	.20	.55	.66
FeO	2.44	2.65	2.83	6.57	3.27	2.58
MnO	.21	.08	.37	.15	.81	.20
CaO	3.92	4.44	6.70	4.73	4.46	7.07
MgO	2.71	1.88	2.46	2.84	1.64	2.20
K_2O	1.14	1.88	3.18	2.63	3.60	3.57
Na_2O	3.20	4.54	3.70	3.04	3.02	2.95
H_2O	.29*	4.69	3.35	-	4.04	3.45
H_2SO_4	.37	-	-	Trace	-	-
Loss	4.81	-	-	1.98	-	-

* This is CO_2 (sic).

Duncan's Dubs and Rennieston are non-pining sites.

The analyses disclose some variation in the proportion of basic matter at different centres.

At Whitton Hill, for example, there is approximately double the amount of lime and potash in the rock compared with Cocklawfoot. All centres have appreciable quantities of iron. This gives a characteristic pinkish or reddish colour to the surface of many of these rocks and also to the soils of the area. The iron content is specially noteworthy in view of the association of iron compounds with pine disease.

The rocks have the typical porphyritic structure showing a ground-mass of compact material in which are set isolated crystals, or phenocrysts, of plagioclase felspar, biotite, etc. The colour in fresh exposures varies from a blackish grey to pink, or bluish pink. Near the surface this alters to a deeper pink or to a reddish colour. There is often much staining and kaolinization. The rock usually exhibits a somewhat coarse-grained texture and is often referred to by farmers as "spotted rock" or "bastard rock". This is also due to the amygdaloidal structure which Geike states is the most characteristic feature of these rocks as a whole. The steam vesicles are filled with various compounds such as quartz, agate, calcite, and zeolite, giving a spotted appearance, particularly at or near the weathered surface. In coarse samples they are about 4 mm. by 4 mm. The majority of fresh samples have been found by the writer to effervesce to a moderate extent when treated with hydrochloric acid. The ferro-magnesian constituent is occasionally biotite.

Samples of rock from Middlesknowes, Jedburgh, were classified by Dr. Campbell of the Geology Department, Edinburgh University, as Biotite-Andesite.

The coarser textured Andesites sometimes weather into nodular fragments with a rounded or cylindrical shape owing to seepage water and frost action setting up decomposition. In some places, deposits of this broken rock are found to some depth forming natural "quarries". The material is carted off by farmers for use as gravel around their premises. The term "rotten rock" is often applied in view of this pecularity in weathering.

From the pastoral and agricultural points of view, the main significance attaches to the texture of the particular variety of Andesite. The writer examined samples from all over the area and has been able to correlate pining with this feature to a considerable extent. This part of the survey may be summarised by stating that on those farms where pining is worst, the rock is usually more coarsely granular and more easily shattered than in less affected places. It gives rise to an open gritty soil from which the finer material is readily washed away. Where pining is less severe, the texture is finer, the rock is harder, and the soil to which it gives rise is heavier. On the hardest type of Andesite pining is absent.

Physiographic features in relation to Pining.

It has been shown (60) that Bush Sickness in New Zealand is associated with light, open soils at high-lying locations which are elevated above the permanent water-table and therefore provide favourable conditions for soil aeration and leaching. Large flats of land at these altitudes in New Zealand are most affected with the malady. The greater the elevation of this type of land the greater the tendency to the disease. Godden and Grimmett (25) applied the New Zealand analogy to the Cheviot region but thereby have fallen into error. There is not necessarily any such connection between pining and elevation. Indeed, the higher lying land on many farms is least affected with pining. This is true of The Arks, Cocklawfoot, Hounam Mains, Middlesknowes, and others.

Various factors may come into play at high elevations, and provide better soil conditions than lower down. Climatic peat, for example, is produced more readily owing to the more humid conditions, and this tends to act as a filter which modifies the action of leaching. It also supplies colloidal material which reduces the aeration of the soil constituents after the manner of clay. Many of the grassy East Border Hills have a thin layer of climatic peat or humus, one or two inches thick, above the 1,000 feet level. Beyond this height, therefore,

soil conditions as far as pining is concerned may tend to improve with increased elevation.

The deepest and finest textured soil is often found in the upper reaches of many farms, around the burn-heads. In these places the cutting action of burns, streams, and surface water is smaller. There is no great sweep of water to carry away the covering of soil. Soil erosion is much less active.

One may carry the matter a stage further and visualise the land features of a typical valley as a whole. It will be found,as a rule, that in hill country as one ascends the valley from the lower and middle reaches towards the watershed, the better is the land and the sounder and healthier are the sheep farms. The best farms will be found at the head of the valley itself. There are exceptions but the general principle holds good. It is true of the majority of valleys in the Borders, including Borthwick Water, Bowmont Water, the Vale of Ettrick, Eskdale, Jed Water, Kale Water, and Teviotdale. It also applies in many Highland areas, of which Glen Affric is a notable example. This phenomenon is partly explained by the fact that as one proceeds downstream from the source, the valley becomes more deeply trenched, the gradient of the valley sides increases and this quickens the processes of leaching and erosion. The covering of soil therefore becomes thinner and coarser, the herbage is inferior and

liable to burn, and the stock are not so healthy. In the upper reaches, on the other hand, there are often greater areas of deep land even on the slopes, and there is a much better mixture of all classes of herbage. The conditions are more favourable for the formation of peat mosses which produce draw moss and heather of the best type.

From what has been stated, it will be apparent that pining is more likely to arise in a severe form at middle and lower elevations on the Andesite. This is generally so, though the shallowness of the land over the area as a whole is a more pronounced feature than in most Border valleys.

Soil Structure.

On typical shallow land which is so prevalent on the Andesite, the soil structure is of the most rudimentary type. A profile taken on the upper slopes of Peg Law, Jedburgh, where many of the experiments with sheep were carried out as referred to later, is described below.

(1) Soil on the upper slopes of Peg Law, Jedburgh.

UNDERLYING ROCK	Andesite.
PARENT MATERIAL	Andesite.
TOPOGRAPHY AND ELEVATION	Moderate to steep slopes, 700 - 900 ft.
RAINFALL	40 ins.
DRAINAGE	Good.

VEGETATION		Agrostis and Fescue. Well grazed.
PROFILE DESCRIPTION	1. 1-2"	Vegetable debris and fibrous mat.
	2. ¼-½"	Black Amorphous humus.
	3. 1-4"	Dark reddish brown layer; coarse, gritty, and friable; stony; roots present.
	4.	Rock.

The above profile may be taken to represent the upper slopes of individual hill tops at elevations up to about 1,000 feet. Beyond this elevation, the layer of humus tends to increase, or the humus may be incorporated with the soil.

These shallow soils appear to be bone dry for the greater part of the year. Nevertheless, they carry an exceedingly dense covering of leafy herbage which only seriously burns in a dry summer.

A typical soil profile at the bottom of slopes where a deeper soil has formed is described below.

(2) Soil at the base of Peg Law, Jedburgh.

UNDERLYING ROCK		Andesite.
PARENT MATERIAL		Silty matter from Andesite slopes. Perhaps some glacial drift.
TOPOGRAPHY AND ELEVATION		Slightly sloping; 600 ft.
RAINFALL		40 ins.
DRAINAGE		Fairly free; flush.
VEGETATION		Aira caespitosa.
PROFILE DESCRIPTION	1. 0-½"	Vegetable debris and fibrous mat.

2.	0-¼"	Black amorphous humus.
3.	6-8"	Fine silty loam; dark slaty colour; fairly compact; roots.
4.	10-12"	Bluish clay; mottled red, particularly along root channels; compact.
5.		Rock.

A profile taken on a site above rotten rock is as follows.

(3) Soil on Rotten Rock.

LOCALITY	Riccalton, Jedburgh.
UNDERLYING ROCK	Andesite.
PARENT MATERIAL	Andesite.
TOPOGRAPHY AND ELEVATION	Rolling, 620 ft.
RAINFALL	40 ins.
DRAINAGE	Good.
VEGETATION	Agrostis, Fescue, Nardus.

PROFILE DESCRIPTION

1.	1"	Vegetable debris and fibrous mat.
2.	¼"	Black amorphous humus.
3.	6-9"	Dark red-brown layer; coarse, gritty, and friable; roots.
4.	6"	Light reddish-brown layer: mainly stone with earthy matter; very hard and compact.
5.	36"	Light red rotten rock; (yellow or orange on exposed surface); readily shattered with pick; fragments 2 cm. by 1 cm.
6.		Rock.

On another location, at Upper Chatto, the rotten rock was of a brownish-grey colour, this being more typical than the red colour in profile (3), described above.

On locations under Molinia at Middlesknowes, the profile was 4" black amorphous humus; 3" light brown fibrous peat with earthy matter; 4-5" reddish-brown loam; 12" bluish clay, very compact. In one or two places in this Molinia area the clay layer was bleached a whitish or greyish colour.

No podsols have been observed on the Andesite and it seems unlikely that they are present to any extent.

Iron pan or "moor band" occurs in a few places. It generally contains a good deal of stony material. It can be seen at a depth of 10-15" under peaty land with a molinia type of herbage at Riccalton and at Browndeanlaws, and under peat with heather at Edgerston Tofts. The impeded drainage in these areas does not appear to have any ameliorating effect on pining.

Analyses of Pining Soils.

Godden and Grimmett (25) investigated the composition of pining soil from a typical area in the Cheviot region. The results are set out below.

Pining Soil.

Mechanical Analysis.	per cent
Fine Gravel	15.75
Coarse Sand	16.74
Fine Sand	15.82
Silt	18.16
Fine Silt	11.40
Clay	1.10
Moisture	8.94
Loss on Ignition	11.16
Matter soluble in dilute H Cl	0.96
	100.03

Chemical Analysis. (on soil dried at 100°C.)	per cent
Nitrogen	0.45
Total P_2O_5	0.14
Available P_2O_5	0.023
Total K_2O	0.45
Available K_2O	0.024
Total CaO	0.061
MgO	0.45
Total Fe_2O_3	2.60
Citric Soluble Fe_2O_3	0.052
Total Mn_2O_3	0.19
Citric Soluble Mn_2O_3	0.043

Lime Requirement 0.52% $CaCO_3$
(equal to 2tons 18cwts CaO per acre)

The outstanding feature of pining soil is the small proportion of clay and fine silt. These soils are dry and light and subject to excessive aeration. They form a poor foundation for the stock-raising enterprise.

The analysis shows a moderately good content of available phosphate and potash. Hendrick (61) gives the figure of 0.01 per cent of available material as usually representing the lower limit of fertility for these constituents. In neither case

do these figures reach this limit.

The soil is rather low in lime, with a Lime Requirement equivalent to approximately 2 tons 18 cwts per acre. There are many soils, however, with a somewhat similar lime requirement, which are not affected with pining.

The figure for available iron shows that this constituent is present in considerable quantities and indicates that the cause of pining is likely to be found elsewhere than in an iron deficiency.

No analyses of herbage are given by Godden and Grimmett.

Cropping characteristics of arable soils on Andesite.

The soils on arable districts on the Andesite are characteristically dry and early. There are no special problems in crop growing. They provide some of the best barley soils in the Borders and are also well adapted for roots. Rotation grass is usually good, both Red Clover and White Clover growing freely with ordinary manuring and treatment. Harvesting, even at elevations of 600 - 800 feet, is usually in advance of low-ground districts in the neighbourhood. There appears to be little about the cropping results in the area to suggest any particular deficiency except in phosphorus, which, however, is a common deficiency of farming land elsewhere. While the land grows remarkably good crops, considering its

mechanical constitution, the farmer is well aware that the produce is lacking in elements necessary for the full maintenance of health and growth in live-stock.

Pining in other districts in the Border Area.

It may here be appropriate to make reference to the occurrence of pine disease in other districts in the Border Counties, apart from the East Borders. Broadly speaking, the disease may be found on any geological formation and in any district. There are two ways in which the disease is manifested in these localities.

In the first place, it may take the form of a regularly recurring disease and involve the changing of the flock on somewhat the same system as in the East Borders. There are many hill farms in this category. On some arable farms also, constant changing between different parts of the farm is necessary. A small pining belt of this nature, which includes hill farms as well as arable farms, lies on Basalt and Dolerite of Carboniferous age on the ridge west of Jedburgh of which Dunian Hill is a prominent feature. Dunian and Black Law hills are volcanic bosses of Olivine-Dolerite (62). Some portions of the Old Red Sandstone adjoining are also pining. The hill of Ruberslaw in the near vicinity, which is a type of Basalt with volcanic agglomerate,

is prone to a mild type of the malady. The Silurian formation in many districts of Roxburghshire and Selkirkshire affords many examples of hill farms where the disease regularly recurs every season. The farms are widely scattered. Treatment with mineral feeding was successfully introduced during the past four years by the writer on

3 farms on the Dolerite,

2 farms on the Old Red Sandstone,

9 farms on the Silurian.

In the second place, pining is found in some districts when the sheep have got into a reduced state, as after a hard winter. A proportion of the ewes may show severe symptoms of anaemia. It may occur in some of the best localities, as in the Lammermuir country. It is also found on some arable farms on the Old Red Sandstone as well as on the Silurian. This is a sporadic type of the malady dependent on the season and the general standard of nutrition, and while the exact cause may not be identical with East Border pining it is significant that it can be both cured and prevented by the same treatment. It has been found that mineral feeding alone, without any supplement in the way of protein or carbohydrate is sufficient to prevent and cure the condition.

Apart from the recognised types of pining referred to above, there is also a form of incipient

anaemia or pining which is prevalent among ewe flocks on all classes of farms and on all soils. Ewes commonly appear to get into a slightly anaemic state during pregnancy, although not always reaching the clinical stage of pining. It is also found among poorly nursed lambs and small lambs after weaning. In a large number of cases, a very marked response has been obtained from applying mineral treatment as for ordinary pining. On some 40 high-ground and low-ground farms in this category, located on all formations in the Border Counties, mineral feeding has been introduced by the writer with great benefit to the stock.

It seems clear, therefore, that pine disease, whether of the endemic, the sporadic, or the incipient type, is a much more insidious and widespread malady than has hitherto been supposed. In the Borders it is associated with soil conditions of a poor type and also of a moderately good type, in practically every district. The evidence furnished by this survey, which has been conducted in one of the best farming regions in the country, seems to suggest that these various forms of pine disease are probably widely distributed elsewhere.

Summary.

The pining belt in the East Borders is mainly situated on the Andesite, or, as it was formerly

called, the Porphyrite formation. Small portions of the Old Red Sandstone and Silurian formations are included in the area, and many farms on these sites are pining also.

There is a correlation between pining and the texture of the Andesite. The coarser grained varieties are most affected with the disease.

Physiographic features of the area require to be interpreted with caution. Pining tends to be worse at middle and lower elevations in hill country, rather than at higher altitudes.

Pining soils on the Andesite are light, and show a low content of clay and fine silt.

Chemical analysis of these soils appears to indicate that there is no lack of available iron.

Pining of the endemic type is found in localised areas on most geological formations in the Border Counties, in addition to the East Borders. A sporadic type of pining which is dependent on seasonal and nutritional conditions is liable to occur in many districts. A form of incipient anaemia, akin to pining, is also common. The same mineral treatment has been successful in dealing with all of these conditions.

It is suggested that pining in one form or another is common in all parts of Scotland.

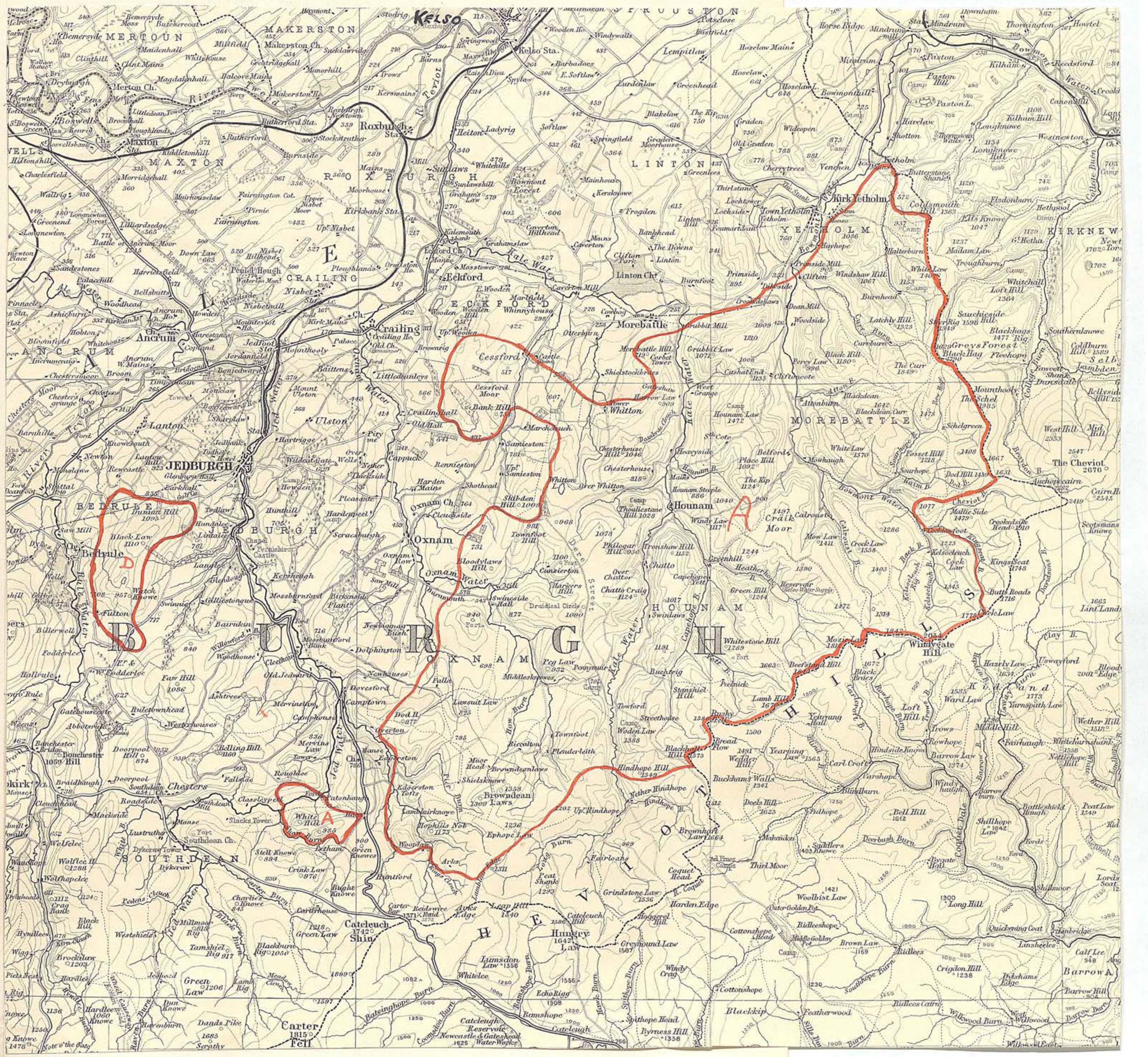
13. MAP SHOWING THE PINING AREA IN THE EAST BORDERS.

During the course of the survey, information was obtained from farmers and shepherds as to the exact extent and location of all pining land in the East Borders. This was plotted on Ordnance Survey sheets on the scale of 6" to the mile. From the data obtained, a map of the pining area on the scale of $\frac{1}{2}$" to the mile has been drawn out and is shown on page 142.

The area marked out on the map includes all land where pining is endemic and where shifting of the sheep-stock has to be carried out in order to keep the animals in health. The fixing of a precise boundary was not always easy, as there are many borderline cases where, owing to the improved state of the land under arable cultivation, pining may not show itself.

While the boundary given on the map delimits the pining area, there are, nevertheless, tracts within the area which are free of the malady. It is not possible to mark these out with any accuracy on a map of this scale. For the same reason, the degree of pining, whether moderate or severe, is not shown. For details regarding these points in any particular locality, reference may be made to the Ordnance Survey sheets prepared by the writer.

As no geological map of the area is available on the scale of $\frac{1}{8}$" to the mile, it has not been possible to include a geological map in this thesis.



A. THE MAIN PINING AREA - APPROXIMATELY 80 SQUARE MILES.

D. SUBSIDIARY AREA ON OLIVINE-DOLERITE, ETC. (NO DATA INCLUDED IN SURVEY.)

14. SOME BOTANICAL ASPECTS OF THE PINING AREA.

Correlation with Pining.

Reference has already been made on page 72 to the general constitution of typical hill grazings in the pining area. On an average of 11 hill farms, it has been shown that 77 per cent of the land is estimated to consist of shallow-land vegetation. Heather on deep moss is almost entirely absent. There is no doubt that a constitution of this kind in any part of the country, taken in conjunction with continuous and fairly intensive grazing by sheep for long periods, is likely to favour pine disease, in one form or another. In some instances, the quality of the soil will be sufficient to counteract anything but a mild tendency to the disease. In the East Borders, however, the deficiency in the land is such as to precipitate the malady in an endemic form. It will be noted that the quality of the soil is the governing factor.

An increase in the proportion of deep-land herbage in a hirsel or heft usually brings about a corresponding reduction in the tendency to pining. Particularly valuable are flush-land herbage and the vegetation of deep alluvial flats. Most valuable of all is heather on deep moss, the importance of which has already been pointed out. It is the exception to find this on the Andesite, but in one or two hirsels

it occurs at a high altitude, and these grazings are almost entirely free of pining.

On the other hand, the occurrence of a high proportion of Nardus in a sheeps' grazing may sometimes go along with an increased disposition to pining. It tends to force the sheep on to the shallowest and poorest land. Again, the predominance of Sheep's Fescue over Agrostis on the sweet ground may point to rather poor soil conditions and indicate some connection with the malady. Bracken is not directly associated with the problem, but on one or two farms it is present to a serious extent and interferes with the grazing of sheep.

Apart from these tendencies, there is little of a botanical nature that can definitely be associated with pining.

Nardus.

Nardus stricta, or Moor Mat Grass, is liable to invade much of the drier and shallower ground which carries the Agrostis-Fescue type of vegetation. A 20 per cent incidence is common, while small areas may contain 50 per cent and upwards of this plant. It is very irregular in its occurrence, depending on grazing conditions and the lie of the ground. Where grazing is most intense it disappears altogether.

On the deeper ground, Nardus is largely suppressed by Aira caespitosa, Molinia, and other

strong-growing species, particularly where these are deeply tufted. It asserts itself, however, among the short thin type of Molinia.

While Nardus constitutes a pest on hill grazings, the accounts of its prevalence and ability to spread which appear in the literature are not always borne out in practice. Fenton (34) states that close grazing by sheep eliminates the competition of surrounding herbage and allows the inedible Nardus to develop. He further asserts that it is always worst where sheep grazing is intensive. This latter statement, however, needs some qualification as it rather tends to imply that the plant will be most prevalent on those areas where there is the heaviest concentration of sheep. The contrary, however, is the case in the East Borders. In a grazing amounting to 292.5 acres, which was surveyed by the writer, details of which are given later, 44.3 per cent of the sweet ground was entirely devoid of Nardus. The reason was that grazing was most intensive on those parts. The resulting turf was so dense and leafy and so continuously cropped and manured by the sheep that the plant was unable to gain a footing. This coincides with the experience of most farmers in the area.

The term "Nardus dominant" frequently appears in the literature without data to show the actual occurrence of the plant. One is left in doubt as to

the exact significance of the title. A grazing may appear to have a considerable amount of Nardus, while actual measurement may show it to be rather a subsidiary species. In one case, where Nardus was a very prominent feature of the vegetation, and where the writer roughly estimated it to account for one-third of the ground surface, the average of a large number of line-frequency estimations showed that only 17 per cent of the ground was actually occupied by it. The opinion has been formed that much of the land in the district which carries Nardus has a somewhat similar incidence. Although such places show up white in autumn and winter, it would not be strictly correct to call the herbage of these areas "Nardus dominant". Agrostis would probably account for a higher proportion of the herbage than Nardus.

The Occurrence of Bracken.

It is the exception to find Bracken encroaching on hill ground in the East Borders to anything like the extent that occurs in some of the northern and western parts of Scotland. With the help of farmers and shepherds, an estimate was made of the acreage of Bracken on 14 farms in the area. These farms comprised 27 hirsels and extended to 16,844 acres of hill land. It was found that some 3,518 acres, or approximately 20 per cent of the land, is actually covered at the present time. This includes both thin and thick

Bracken. Particulars are set out in the table below.

TABLE SHOWING ACREAGE OF BRACKEN
ON 14 PINING FARMS IN THE EAST BORDERS.

No. of Hirsels	27
Total Acreage of Land	16,844
Acreage of Bracken	3,518
Percentage of Bracken	20.88

No. of Hirsels without Bracken	3
" " with 1-10% of Acreage	10
" " " 11-25% "	7
" " " 26-40% "	2
" " " 41-50% "	3
" " " 51-65% "	2
" " " over 65% "	-
	27

It will be seen from the table that on approximately one-half of the 27 hirsels there is either no Bracken at all or an acreage not exceeding 10 per cent On these grazings, therefore, there is no bracken problem, as the small acreage could readily be dealt with by systematic cutting.

On the remaining hirsels, and particularly on 5 of them which contain over 40 per cent of Bracken, the problem urgently requires to be tackled. A public demonstration was arranged in the district by the writer in 1935 when two types of cutting machines

were put to work. The results showed that the plant could be suppressed at a moderate cost per acre by taking a definite section each year and cutting it over three times or thereby. The all-in cost amounted to about 1/3 per acre for each cut. The land in most cases is fairly accessible to implements.

It would be a mistake to regard the whole of the Bracken area as more or less lost to sheep. Much of it is thin short Bracken through which sheep readily pass. In a dry summer such areas maintain their herbage in a fresher state than on places where there is no corresponding cover from the sun. The main drawback is that the grass is less able to withstand autumn frosts. From an examination of many areas and the evidence supplied by farmers, it is estimated that less than 50 per cent of the bracken land is inaccessible to sheep.

Bracken is only found on the drier and rather shallow parts of hill land, and ends abruptly on the edges of the deeper and moister ground. It is associated with the Agrostis-Fescue type of herbage. It is also one of the great competitors of Nardus. Nardus is a light-demander and cannot tolerate the shade of Bracken. Where the covering is thin, a beautiful clean sward of grass is produced below it, from which Nardus is entirely absent.

There is no direct correlation between pining

and Bracken. Some of the worst pining hirsels have less than 5 per cent. It contributes to the malady, however, on some of the more heavily infested places.

Under the headings which follow, it is intended to make short references to each of the major types of plant settlements found on hill grazings in the pining area, apart from the occurrence of Nardus and Bracken. These are usually well defined, the vegetation of the deeper and moister ground standing out in high relief, while on thinner and drier ground the herbage is mainly reduced to bottom plants. In the normal way, sheep on typical hefts in the East Borders have a run of from 200 to 300 acres which includes many different types of herbage. A short description, therefore, will give some idea of grazing conditions on pining land. Plant associations on hill land have been described for other areas (63), but more from the botanical than from the pastoral point of view.

Areas under Molinia.

Molinia caerulea, or Flying Bent, frequently forms the dominant constituent over areas of deep or moderately deep land where drainage is bad and water tends to lie stagnant. A peaty layer is formed to some depth from the accumulation of vegetable debris, and this tends further to impede the drainage. Surface drains and ditches get blocked up with the

withered foliage and flowering stems which are carried away by the wind. In the Borders, the plant is usually referred to as Bent.

Associated with Molinia is Aira flexuosa, which is winter-green and affords a slight amount of sustenance. There also occurs a thin sprinkling of Sweet Vernal Grass, some struggling plants of Blaeberry (Vaccinium Myrtillus), and Heather (Calluna vulgaris). Where Molinia is not too deeply tufted, Stool Bent (Juncus squarrosus) may be plentiful, while on the wetter portions, Deer's Hair Grass (Scirpus caespitosus) may occur in patches. On shallower soil, Molinia grows more on the flat. It is thinner and shorter and may be accompanied by a good deal of Nardus.

Molinia itself dies back to the root-stock in winter and provides no winter grazing of any kind. The only herbage of value on this land at that time is the thin sprinkling of other species associated with it. Apart from this and some young growth in early summer, the tracts of Molinia form the most useless of any section of vegetation in the East Borders. It is not eaten by sheep except in the very early stages and comes too late to be of much assistance. In some instances, it is cut for hay but is unable to stand repeated cutting.

The approximate composition of a "pure" Molinia area was estimated by 30 line-frequency

determinations taken in April. These gave the following results.

	per cent of surface
Tufts of Molinia	33.0
" Juncus squarrosus	8.3
" Green Moss	3.0
" Nardus	1.5
Molinia untufted, with subsidiary species	54.2
	100.0

The soil profile is that given on page 133. The soil under Molinia is often some of the best in the grazing. Improvement of these areas would spread the sheep and would represent a clear gain to the grazing in nutrition and hygiene.

Heather.

Heather may occur on mineral soil with a slight admixture of humus, or with a thin covering of one or two inches of humus, when it is known as lea heather. It never grows strongly in such places and tends to be suppressed by sheep. Heather growing among Molinia also suffers from the onslaughts of sheep. In the absence of any large proportion of heather from the grassy hill-land of the East Borders, reliance has to be placed upon Aira caespitosa and Mixed Deep-land herbage for winter grazing, together with a supplement of hay.

Areas under Aira caespitosa.

In deep-land areas where the surface is liable to flooding, but in which the water does not lie stagnant, the dominant herbage is Aira caespitosa. It is the main indicator of deep-land on mineral soil. Where the conditions are wet for long periods, Rushes may become plentiful. Aira caespitosa also occurs where flush conditions prevail on any contour and on any depth of soil, but it requires deep land for proper development.

Nineteen line-frequency determinations of the vegetation, taken in April, gave the following results.

	per cent of surface
Tufts of Aira caespitosa	25.28
" Agrostis-Fescue	5.0
" Rushes	2.78
Partly bare ground and some bottom herbage	66.94
	100.00

The tufts had an average depth of 8 inches, above the surface. In summer, the strong foliage covers most of the spaces between the tufts. There was a slight amount, however, of bottom herbage composed of Agrostis, Holcus, Anthroxanthum, Poa, etc. The soil profile on one of the sites is given on page 131.

Aira caespitosa is by far the most valuable

plant in stormy periods in winter. The plants are never without young green shoots, while the outer leaves retain a green shank several inches long. Frost appears to soften this coarse material. The root-stock is succulent and edible. When snow is deep it can be scraped away from these tufts more easily than anywhere else. A grazing with a good proportion of this class of herbage is well fortified to withstand a severe winter.

Mixed Deep-land Herbage.

Where drainage is of an intermediate character being slightly impeded, one gets, on deep land, a mixed herbage composed of Aira caespitosa, tufts of Agrostis-Fescue, Molinia caerulea, Nardus stricta, Juncus articulatus (Spret Rush), Juncus squarrosus, and a bottom herbage of Agrostis, Holcus, Anthoxanthum, Poa, etc. In this case the soil generally shows a surface accumulation of humus to some depth. Thirty-two line-frequency determinations, made in April on typical areas, gave the undernoted average results.

	per cent of surface
Tufts of Aira caespitosa	12.0
" Agrostis-Fescue	13.0
" Molinia	9.0
" Nardus	9.0
" Juncus squarrosus	3.3
Juncus articulatus, bottom herbage, etc.	53.7
	100.0

This is one of the most valuable classes of land, as it provides a variety of herbage at all seasons. It is particularly useful in winter.

Agrostis-Fescue on Deep Land and Semi-deep Land.

The Agrostis-Fescue class of vegetation as a whole usually occupies by far the largest proportion of the land on hill grazings in the East Borders. It will seldom account for less than 50 per cent of a heft or hirsel. For pastoral purposes, three main types may be recognised, according to the character of the soil on which it is produced, namely, (1) deep land, (2) semi-deep land, and (3) shallow land. They all occur under comparatively dry soil conditions where there is free drainage at all seasons. They also represent the areas which tend to be most grazed by sheep.

On deep land, this class of herbage may either be closely grazed like the sweet ground on shallow soil, or it may get into rather a rough tufted condition. Much depends upon the proportion it occupies to the rest of the grazing. The herbage itself contains rather a higher proportion of Agrostis and a less proportion of Sheep's Fescue than on shallow soil.

The Agrostis-Fescue vegetation on semi-deep land grows stronger and rougher in summer than on shallow ground, with a much greater proportion of flower stalks. The tufted habit is a noteworthy

feature. It can readily be distinguished by these characteristics. Along with rough herbage of a similar type on deep ground, it provides a reserve both of summer and of winter fodder. In periods of hard frost, sheep can often get green herbage free of frost by working in this ground. The shallow-land vegetation may be quite useless at such times.

A distinction is necessary between these different types, otherwise a clear idea of the character and potentialities of a grazing cannot be obtained.

The Agrostis-Fescue vegetation of the shallow ground is dealt with in considerable detail in succeeding paragraphs.

Agrostis-Fescue on Shallow Land.

This constitutes the sweet ground, or fine ground, from the short leafy herbage it produces. It may also be found on deep land, as already mentioned, but only to a small extent in the East Borders. The use of the term "sweet ground" is hereafter reserved exclusively for shallow land, unless otherwise stated.

Sweet ground or fine ground is the predominant feature of the herbage of hill land in the pining area. It occurs on shallow ridges and knowes and on many hill slopes, but may occupy large tracts of the grazing irrespective of contour. The herbage mainly consists of the Agrostis-Fescue association, but on

areas rendered moist by flush water, Aira caespitosa is sometimes found though the plants are small. Nardus may be prevalent, as already noted, on portions which are less intensively grazed by sheep. All the sweet ground is much matted, showing 1-1½ inches of living fibre and roots where grazing is close and regular. The mat may increase to as much as 8 inches in rougher places.

A common tendency on parts of the sweet ground, usually on the flat tops of hills, is for the herbage to assume a tufted or tussocky habit. Some 50 per cent of these areas may be covered with rounded tussocks 12-18 inches across, and rising about 6 inches above the surface. There is a very deep mat underneath. The herbage consists of Sheep's Fescue in the centre with a fringe of Agrostis and Poa around the margins. The herbage is less well grazed than in the intervening spaces and so the layer of surface fibre grows upwards each year. These clumps provide shelter for the herbage growing between and also act as a reservoir for water. Any disturbance in the way of "improvement" would destroy the accumulated vegetation, and the underlying layer usually consisting of no more than 1 inch of soil would probably be washed away.

There is usually a fair amount of winter grazing on the sweet ground up to the turn of the year, particularly after a growthy autumn. In hard

or snowy weather, however, it is inaccessible to sheep.

Botanical Composition of Pining Sweet Ground.

The botanical composition of the sward on pining land was ascertained in some detail. The rough and ready method of percentage frequency was discarded in favour of the percentage weight method. Samples were taken from the open hill on different parts of Peg Law, Jedburgh, the top of the hill, both tufted and untufted, and the sides being all included. The elevation was 650 - 800 feet. Nardus is almost entirely absent from this hill, and any samples showing the plant were excluded. The depth of fibrous mat was 1-4 inches and the soil covering 1-4 inches. The soil profile is stated on page 130. The conditions and the nature of the herbage are typical of much of the sweet ground in the East Borders.

Four samples were taken in July 1935, eight samples in July 1936, four samples in April 1937, and one sample in July 1937. The first four samples were of cut herbage, each taken from half-a-dozen places. The remaining samples were turfs. Each sample was separated into its different constituents and weighed. Dry matter estimations were made of the constituents of eight different samples.

The following statement shows the average composition of the sward.

BOTANICAL COMPOSITION OF PINING SWEET GROUND.

PEG LAW, JEDBURGH.

	Green Weight (Average of) (17 samples) per cent	Dry Matter per cent
Agrostis vulgaris	38.49	34.37
Agrostis canina	Trace	Trace
Festuca ovina	42.88	47.74
Other Fescues	Trace	Trace
Poa pratensis.	9.28	8.22
Holcus mollis	4.01	3.77
Anthoxanthum odoratum	.54	.52
Aira caespitosa	1.61	2.92
Luzula campestris	1.55	1.40
Galium saxatile	1.08	1.02
Miscellaneous: Trifolium repens, Rumex acetosa, Campanula rotundifolia.	.56	.04
	100.00	100.00

The analysis showed that by far the greatest proportion of the grazing was composed of Agrostis and Fescue, these species together contributing 82.11 per cent to the total herbage, in terms of Dry Matter. The relative proportion of these two grasses varied in different samples. In eight cases there was more Agrostis than Fescue, while in nine cases Fescue was in the ascendant. Only a trace of Agrostis canina was present. There was also only a trace of other Fescues besides Festuca ovina.

Poa pratensis accounted for 8.22 per cent, while Holcus mollis gave 3.77 per cent. There was little or no White Clover. Crested Dog's Tail was entirely absent.

The amount of green Moss (Hylocomium) was estimated in most samples but is excluded from the above table. When reckoned in with the other constituents, it amounted to 11.92 per cent of the total Dry Matter.

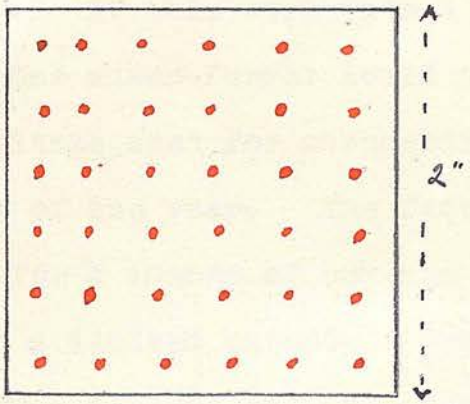
An outstanding feature of the herbage was the high proportion of leaf and leaf-bud, and the relative absence of flowering stem. Separate weighings of leaves and flowering stems were made in all cases. In the 13 samples which were taken in July, 95.6 per cent of the green weight of the herbage was leaf, and only 4.4 per cent was flowering stem. Stems were short, spindly, and green at the time of weighing. These figures well illustrate the dense sward of foliage which is produced on the sweet ground by the constant grazing of sheep.

Density of Turf on Sweet Ground.

The turf forms a dense carpet of foliage on the sweet ground even in places where it may rest almost directly on the solid rock. Southerly exposures, however, on these places suffer from drought.

A count was made of the number of shoots occurring in 3.29 square feet of herbage comprising

seven turfs. This showed 4,425 separate shoots of different species with leaves attached, each shoot being considered capable of producing a flowering stem. The density therefore amounted to 9.30 shoots per square inch of surface. Festuca ovina provided by far the greatest number, followed by Agrostis. The average density of the turf as regards leaf-bearing shoots is shown in the undernoted diagram.



The weight of the shoots in July was estimated for the principal species in the case of five samples.

	No. of Shoots	Weight gms.	Weight of 100 Shoots
Agrostis vulgaris	852	85.11	9.98
Festuca ovina	2,646	88.90	3.36
Poa pratensis	182	13.30	7.30

Even in the case of the larger shoots, namely, those of Agrostis, 100 of them at the period of maximum growth in summer weighed little more that one-third of an ounce.

It will be noted from the foregoing that the

herbage of the sweet ground is relatively fine in character, and consequently extremely attractive to sheep. These data fully explain the urge exercised upon sheep to settle and feed on this shallow pining ground, particularly those sheep which are in the opening stages of the malady.

It is curious how the view has crept into the more popular literature that sheep will always seek out the type of grazing necessary to keep themselves in health. If this were indeed true, most of the problems of the sheep-farmer would disappear. There would be little need for shepherding throughout the greater part of the year. The fact is that hill sheep will look for a change of herbage in their own interest only to a limited extent. Orr (64) analysed grass from "eaten" and "uneaten" hill pasture and concluded that the sheep left the "uneaten" herbage because it was poorer in mineral matter. This, however, is only one factor in the question and may be entirely over-ruled from the sheep's point of view by other considerations. It is significant that in the figures published by Orr the "uneaten" herbage contained more fibre than the "eaten". The habits of the grazing animal, however, cannot be interpreted from chemical data alone. The herbage must be in a suitable form, otherwise sheep will neglect it. Fine benty hay, for example, from old exhausted meadows is usually preferred to the highly mineralised but

relatively coarse material from low-ground farms. In the present instance, the high palatability of the sweet ground, its relative dryness, its bareness, the accessibility of its lawn-like surface, will always attract sheep irrespective of mineral content.

Yield of Herbage per acre on Sweet Ground.

Given suitable conditions of moisture, the yield of herbage from this type of land is considerable. Two enclosures, which together amounted to 87 square feet, were fenced off on the middle slopes of Peg Law in order to arrive at an estimate of the yield of herbage. There was 1 inch of mat, 4 inches of soil, and the exposure was easterly. Cuts were made in July and September 1937. The weight of Dry Matter was ascertained.

1937	Green Weight per acre. tons	cwts	Dry Matter per acre. tons	cwts
July 26th	4	6	1	6
September 28th	1	7	-	8
Total	5	13	1	14

The composition of the herbage may be taken as approximately similar to the average composition given on page 157.

While admitting that the plots were relatively small and that the year 1937 was comparatively wet, the point emerges that large stretches of shallow pining land at elevations of around 1,000 feet produce

a yield of herbage comparable to good pastures in arable districts. It may be mentioned that this particular hill regularly carries two ewes with lambs per acre in summer. The explanation probably is that this kind of ground has always been intensively grazed and manured by sheep for generations. The accumulated mat with its great range of fibre, or stolons, is capable of storing up considerable reserves of food material at certain periods. The produce largely arises from manurial residues which are partly taken from other sections of the grazing. Probably only to a small extent does the herbage come directly from the soil itself. This is certainly the case where the soil-covering reaches vanishing point but the herbage still goes on producing.

Green Winter Herbage on Sweet Ground.

Green meat in winter is of much value, particularly for the pregnant animal. Apart from contributing an element of succulence to the diet and its valuable laxative properties, it provides a source of Carotene from which Vitamin A can be synthesised (65). This vitamin is often lacking from the diet of stock housed in winter.

Observations on this point were made on the herbage of sweet ground on Peg Law. The herbage of the sweet ground remains vegetatively active in winter to a greater extent than on other sections. Samples

were cut from open ground that was being grazed over in the usual way. Dry Matter was ascertained of both the green herbage and the withered herbage in the samples.

	1936 Dec. 30th	1937 March 30th
Green Herbage		
Dry Matter %	27.4	16.2
Withered Herbage		
Dry Matter %	72.6	83.8
	100.0	100.0

The herbage at both dates was entirely composed of foliage and shoots, without flowering stems. It was from 3-5 inches long in December, while in March it was 2-4 inches long. About 30 per cent of the ground, however, was then entirely bare. There was hard frost and much snow throughout March. It will be seen from the table that the vegetation retained a considerable content of green material throughout the winter, irrespective of weather.

At the end of December, 27.4 per cent of the total herbage was green material. There was a total of 12 cwts. per acre of Dry Matter on the ground. By the end of March, the proportion of green herbage had become reduced to 16.2 per cent, while the amount of Dry Matter per acre had fallen to 5 cwts. not including moss. Much of it consisted of rather fibrous material probably of little value to sheep. It will be seen, therefore, that hill sheep on

grazings of this kind are never at any time deprived of a supply of green herbage so long as the ground remains open. In hard weather, some green meat can be obtained in the deep land.

The composition of the green herbage in December and in March was ascertained in terms of Dry Matter.

COMPOSITION OF GREEN HERBAGE.

	Dry Matter.	
	Dec. 30th	March 30th
	%	%
Agrostis vulgaris	32.35	30.4
Festuca ovina	38.58	50.0
Poa pratensis	27.63	14.4
Holcus mollis	1.2	4.2
Luzula campestris	.24	1.0
	100.00	100.00

All species were well represented in the green herbage of sweet ground in winter. The above analyses seem to bear out that the green herbage of Festuca ovina and Holcus is not so readily eaten as that of Poa and Agrostis.

As regards winter-greenness generally, the young shoots of most species are able to withstand the winter, whereas much of the more mature herbage of the previous season dies back. Such species as Aira caespitosa, Aira flexuosa, and Festuca ovina, however, retain the lower portions of most of the old leaves intact. Juncus squarrosus and Luzula

campestris are, of course, almost entirely winter-green. Molinia and Juncus articulatus, on the other hand, disappear altogether. Newton, quoted by Marshall (66), found that winter-green tissues have the faculty of transforming the free water of their sap into a gel, or colloidal form, which does not produce ice crystals at low temperatures. Some of the above hill plants are able to adapt their mature herbage to winter conditions in this way to a much greater extent than appears from a casual examination of the surface of the grazing.

Spring Herbage on Sweet Ground.

Some observations were made on the composition of spring herbage on this land. Samples were taken from the 20th to 22nd April, 1937, while hill lambing was in progress. The season was earlier that usual for grass. The outstanding feature was the rise in the proportion of Poa pratensis which is one of the earliest of grasses. In the fenced enclosures, the shoots of Poa pratensis were from 3-5 inches long on April 20th; Holcus 3-4$\frac{1}{2}$ inches; Festuca ovina 2-3 inches; and Agrostis 1$\frac{1}{2}$-3 inches. This corresponds with the relative earliness of growth of these species, details of which were recorded over two seasons.

Regarding the proportion of Dry Matter contributed by Poa pratensis in spring, samples which were taken on April 20th from the fenced enclosure where

the herbage was uneaten showed that 30.2 per cent of the total green herbage was composed of this species. The average of 7 determinations from the open hill at this date gave 20.17 per cent. These compared with an average of 8.22 per cent in spring and summer, as stated on page 157. It is apparent, therefore, that Poa pratensis, while it is a minor constituent of the sweet ground in summer, is one of the most valuable in spring when new grass is of paramount importance. It is probably not the most palatable of species, but fills an important place.

When the sweet ground comes away, the deep land also comes away. Aira caespitosa is indeed earlier than any sweet land herbage. The deep ground, however, is much encumbered by debris from the previous year which tends to delay the growth of much of the bottom herbage as far as providing a supply of meat is concerned. Sweet Vernal Grass is prominent at this time. Molinia in 1937 remained completely dead till May 13th. In some years it is much later. This plant is useless for any productive purpose at the period when it is most required.

Considerable prominence has been given to the composition and characteristics of the vegetation on sweet ground. The reason is that this kind of land more readily lends itself to record and observation. It also represents a larger proportion of ground on pining farms than any other section of the grazing.

The Herbage of a Non-Pining Farm.

Enough has been stated in the preceeding parts of this section to show the general characteristics of the herbage on pining land. In order to make a comparison with non-pining land, a farm was selected just across the pining boundary. It lay at a similar altitude and ranged more or less within the same contours as the pining grazings already referred to, and the grazing described in detail on page . The vegetation was predominantly grass with a number of patches of heather well distributed throughout, growing on moss. The heather acreage was estimated to account for 14 per cent of the land. The underlying rock was the Calciferous Sandstone series of the Carboniferous formation, and the soil was a fine silty loam. Viewed from a distance, there was nothing about the vegetation to indicate in what category the land might be placed as far as pining is concerned. The stock remain on this grazing without a change throughout their lives. Pining is unknown.

Botanical analyses were made of the herbage of the sweet ground on this farm. Three samples of cut herbage were taken in July 1935, and five turfs in July 1936. The constituents were separated and weighed green, and the Dry Matter calculated. The undernoted table shows a comparison between this herbage and the herbage on pining land.

BOTANICAL COMPOSITION.

	Pining Sweet Ground Dry Matter %	Non-Pining Sweet Ground Dry Matter %
Agrostis vulgaris	34.37	50.67
Agrostis canina	Trace	Trace
Festuca ovina	47.74	19.33
Other Fescues	Trace	Trace
Poa pratensis	8.22	10.10
Holcus mollis	3.77	12.19
Anthoxanthum odoratum	.52	5.19
Aira caespitosa	2.92	-
Luzula campestris	1.40	.14
Galium saxatile	1.02	.40
Cerastium triviale	-	1.86
Miscellaneous	.04	.12
	100.00	100.00
Flowering stems : per cent of total herbage	4.4	4.6

The botanical analysis showed that while the sweet ground on the non-pining land comprised an Agrostis-Fescue association, it included a higher proportion of broad-leaved species, namely, Agrostis, Poa, Holcus, and Anthoxanthum, than on pining land. There was a much smaller proportion of Festuca ovina. The small proportion of the herbage represented by flowering stems was similar to pining land. The

above composition, however, is similar to that found in sweet ground on the deep land on pining farms. The most that can be said about these analyses is that shallow pining soils are generally associated with a fairly high proportion of Festuca ovina.

As regards the proportions of different classes of herbage, the acreage of sweet ground was much less than usually occurs on pining farms. The acreage of heather could not be taken to account for much difference as many pining farms show more. There was more Mixed deep-land vegetation, however, and more of the herbage associated with Aira caespitosa. The real distinction between the two farms was the character and depth of soil.

The sweet ground mentioned above was on deep land, not on shallow. Instead of the thin open soil of the pining land, the soil-structure in this case was - 1-2 inches vegetable debris and fibrous mat: 4-5 inches brown silty loam; 10 feet bluish clay, streaked red in the upper layers. In some parts, there was 4-5 inches of black humus superimposed on the soil, or partly mixed with it. While pining farms generally have a higher proportion of shallow land, this farm was deep all over.

In conclusion, it may be said that the herbage is mainly of value as an indicator in so far as it reflects the character of the soil, the proportion of different classes of soil, and the soil-water relation-

ships. Features that will generally indicate that pine disease in an endemic form is unlikely are :-

1. Over 30 per cent of heather on deep moss.

2. A high proportion of the sweet ground on deep land of good quality.

3. An abundant acreage of Mixed deep-land herbage, and of Aira caespitosa.

Somewhat similar conclusions were arrived at by MacGowan and Smith (8).

Summary.

1. With the exception of heather on deep moss, there is no class of herbage, as such, which is sufficient to act as a safeguard against pining. The decisive factor is the soil itself.

2. The proportion of different classes of vegetation present in a grazing other than (1) will afford some clue as to whether pining is likely to be severe or moderate.

3. Where there is a high proportion of shallow land with much Festuca ovina, severe pining may often be looked for.

4. Nardus and Bracken may tend indirectly to favour pining on some farms.

5. A classification is given of typical plant settlements on grazings in the pining area.

6. Botanical compositions on a percentage-weight basis are given for shallow pining land carrying the Agrostis-Fescue association.

7. Observations are recorded regarding yield of herbage, turf density, winter and spring herbage, and the herbage on non-pining land.

15. THE CONSTITUTION OF A REGULAR SHEEPS' GRAZING IN THE PINING AREA.

While several surveys of the botanical content of hill pastures have appeared in the past, there has so far been no attempt in Scotland to form an accurate estimate of the area comprised within a regular sheeps' grazing by different plant settlements, and the part they play in the economy of the grazing. This can only be done by actual measurement. Without some conception of the precise areas covered, little idea can be formed of the range of grazing available to the sheep in practice, and, in particular, of the amount of winter grazing. It must be remembered that the dominant factor in sheep-husbandry is the amount and character of the winter herbage on the ground. On this depends the rate of stocking and all that arises from it. Grazings that differ widely in this respect may be passed over without comment in the ordinary survey. Too often the survey becomes an end in itself, instead of a part of a much wider problem. In such cases, it largely ceases to be of practical significance.

The survey recently made of the grassland of Wales (67) will serve in some respects to illustrate this point. Stapledon, while stating at the outset that the enquiry was concerned only with the agricultural uses of land (68), makes no reference at all

to the part played by any of these hill pastures in the sheep-farming enterprise of Wales. Land improvement, however, cannot adequately be considered apart from existing practice. If it is suggested that the herbage alone was under consideration in this survey, the internal evidence of the book may be examined to see how far it satisfies the essentials of a scientific inquiry in this province.

In the first place, the classification of plant communities (69) bears little relation to pastoral use. There is, for example, no distinction drawn between the well-known types of Agrostis-Fescue pastures as they occur in hill districts. There is, therefore, nothing to indicate what proportion of these pastures may partake of the nature of sweet ground and what proportion is rough ground. This information is essential if any idea of the potentialities and value of this class of herbage is to be obtained. Further, the character, depth, and quality of soil on any Agrostis-Fescue areas which were mapped is not stated. Without such knowledge, the herbage alone cannot be regarded as a sure guide to the scope for improvement.

There is no reference to a plant of importance in hill grazings and which gives character to large areas elsewhere, namely, Aira caespitosa. Any mention of this species is entirely omitted from the book. Hooker (72) states it is found "North to

Shetland ... ascends to 3,000 feet in the Highlands". It would be strange indeed if it were not to be found in Wales.

The specific-frequency method of estimating botanical composition, which is of doubtful value for pastoral purposes, was used throughout. No percentage-weight determinations nor any estimates of Dry Matter are given.

The constitution of typical sheeps' grazings in various districts is not referred to.

The main work of the survey was carried out by observation from motor cars (70), and by transecting sample areas on foot. The results were afterwards transferred to maps on the scale of 6 inches to the mile, but large areas were dealt with on the scale of 1 inch to the mile. There is no record of anything in the way of measurement. Anyone who has mapped vegetation in hill country will realise the wide margin of error involved by such procedure. It is certain that without detailed examination of the ground and accurate measurement from fixed points, vegetational types will frequently be shown to occur on places where they do not exist.

Reference is made to the Ordnance and Geological Surveys, and it is inferred that more widespread grassland surveys in this country would be desirable (71). It may be contended, however, that no survey unless accompanied by accurate measurement and unless

done on the scale of at least 25 inches to the mile is worth serious consideration. It seems to be forgotten that the land is well surveyed already by farmers and shepherds. What is required is something that will co-ordinate and extend this knowledge on a scientific basis.

The Constitution of a Pining Grazing described.

A regular grazing, or heft, in the pining area was selected and surveyed in the summer and autumn of 1936 and in 1937. The grazing comprised 292.589 acres of hill land and carried a stock of 260 South-country Cheviot ewes. The area was completely enclosed either with stone dykes or fences, all of which appeared on the Ordnance Survey map except in one case where a fresh line had to be constructed. Details of acreage were also given on the map. With the help of an assistant, the whole of the herbage features within the area were examined in detail and measured off with a chain and a 100 foot tape. The data were transferred to Ordnance Survey sheets on the scale of 25 inches to the mile, or 1 inch to 208.33 feet. Notes were made relating to the character of the soil, and a number of soil profiles were taken.

The grazing extended from an elevation of 575 feet at the lowest point to 1,090 feet at the highest, forming a long and fairly uniform slope, mainly in a westerly direction. There was a moderate gradient

all the way, with some flat land both at the top and at the bottom. It had the shape of a dog's leg, and, taking the average distance from one end to the other, it was 1¾ miles in length. The area was well watered by several streams. There were no rock exposures or bare surfaces anywhere, the whole of the ground being entirely covered with grass. The sweet or shallow ground occurred at various points throughout the grazing, both at high and at low elevations, making the herding of the ground a matter of some difficulty. The grazing had formerly been of a larger size, but a piece of bad pining land at the bottom had been fenced off, with benefit to the stock. There were no cattle on this grazing.

The sheep receive no supplementary feeding of any kind in winter, except a supply of hay when snow is deep or frozen hard. This normally occurs for about three weeks each winter. Lambing begins on the 16th of April, by which time there is generally some new growth on the sweet ground and also on the rougher portions. In some seasons, however, it may partly be destroyed by late frosts.

Further details regarding the pastoral status of this grazing are given hereunder.

Rate of Stocking	0.88 ewes per acre
Lamb Crop, at cutting	94.3 per cent
Gross output per acre (Lambs, Draft Ewes, Wool)	£1 : 0 : 4

Rent of Grazing	£- : 7 : - per acre
Shepherd's Wages	£- : 4 : - per acre
Changing of Flock	£- : 2 : - per acre

This is a grazing with a comparatively high rate of stocking and a large output per acre when compared with most sheep-farming districts in Scotland. It is, however, typical of the better class of farms in the East Borders where gimmers are bred from. The figure of £1 : 0 : 4 per acre representing output is the average of the two years, 1936 and 1937, for prices actually received for lambs, draft ewes, and wool.

On the other hand, the charges are correspondingly high. Rent and the other items mentioned total 13/- per acre, or 14/7 per ewe, but these charges are only part of the costs involved. They do not include such items as the cost of tups, the provision of hay, and the wintering of the ewe hoggs which go on roots for three months each winter. The figures illustrate, however, the comparatively small margin left to the farmer after paying all expenses even in comparatively good years such as 1936 and 1937. It is necessary to add that within the last six years there have been several seasons in succession when the returns barely covered expenses.

The botanical constitution of the grazing is set out below.

THE BOTANICAL CONSTITUTION OF A REGULAR SHEEPS' GRAZING, OR HEFT, IN THE PINING AREA.

	Acres	%
(1) Agrostis Fescue.		
Sweet ground on shallow land (1-5")	136.340	46.60
Semi-deep (5-10")	26.315	8.94
Sweet ground on deep land (10-40"+)	15.145	5.18
(2) Aira caespitosa.		
Aira caespitosa on semi-deep land (8-12")	1.074	.37
Aira caespitosa on deep land (12-40"+)	4.393	1.50
(3) Mixed Deep Herbage.		
Mixed Deep on semi-deep land (8-12")	7.762	2.65
Mixed Deep on deep land (12-40"+)	31.834	10.88
(4) Molinia.		
Molinia on semi-deep land (8-12")	18.148	6.20
Molinia on deep land (12-30"+)	49.288	16.84
(5) Rushes.	1.845	.69
(6) Scirpus-Sphagnum.	.445	.15
(7) Heather.	-	-
(8) Draw Moss.	-	-
Total ...	292.589	100.00

Bracken	Acres	%
Thin	10.044	3.4
Thick	1.386	.47
Total ...	11.430	3.87

The soil profiles are in most respects similar to those described on pages 130-133. The vegetational types, their composition and yield, are those referred to on pages 142-166.

Taking the whole area of this grazing, there emerges the fact that 136.340 acres, or 46.6 per cent of the whole, consists of the Agrostis-Fescue association growing on 1-5 inches of soil resting directly on solid rock. This is a pining grazing partly due to the large extent of shallow ground. Many neighbouring grazings, however, have a higher proportion than this.

The large area of Molinia, covering 23 per cent of the area, tends to force the sheep on to the shallow ground in summer. The proportion of sweet ground on deep land is too small to supplement the shallow ground. There is a complete absence of heather and Draw Moss.

The occurrence of Nardus is of interest. On those portions of the sweet ground which are most grazed by sheep it is entirely absent. Taking the sweet ground on shallow land and on deep land, 67,008 acres, or 44.3 per cent, were found to be completely free of the plant. This does not include sweet ground under bracken which also is devoid of Nardus.

As regards winter grazing, it will readily be realised that the sweet ground with its yield of winter herbage of somewhat similar amount to that

stated on page 163, along with the semi-deep and deep-land vegetation, are together sufficient in an open winter to carry the stock through with no supplementary feeding of any description. In periods of hard weather, however, lasting for any length of time, the relatively small proportion of deep-land herbage and the absence of heather make the provision of hay essential. In the Western Cheviots, on the other hand, there are grazings so constituted that the use of hay is almost unknown.

An interesting point arises regarding the stocking of the sweet ground. The concentration of the sheep on these areas is obviated as far as possible by herding, but, as the shepherd has three separate hefts to look after, the movement of the sheep can only be partially controlled. It is estimated that, in the summer months, three-quarters of the grazing time of the sheep will usually be spent on the sweet ground, both shallow and deep. This is equivalent to a concentration of 1.22 ewes per acre. As a considerable part of the time, however, is actually spent on those portions free of Nardus, namely 67.008 acres, it follows that the concentration on these areas will probably exceed 2 ewes with lambs per acre. This establishes the fact that on certain parts of the grazings of hill sheep the rate of stocking is very similar to enclosed fields in low-ground farms. The mere fact that a very large

acreage is open to the flock does not always ensure an equivalent distribution of the animals. Many diseases of sheep which are associated with intensive methods are therefore just as likely to occur on certain types of hill farms as under semi-arable conditions.

Improvement of the Grazing.

The judicious use of cattle would help to improve some of the rougher portions, and particularly Molinia. As a public road runs through the grazing for a considerable distance, however, this method has been found troublesome in the past.

The shallow ground is highly productive, yielding well over 1 ton of Dry Matter per acre. It is difficult to see how this can be increased economically. It is rather a question of obtaining a better quality of herbage by stimulating white clover. The application of manures such as Ground Mineral Phosphate and Potash has already yielded good results in the district. Strips could be treated here and there. The semi-deep land might be dealt with in a similar manner. with perhaps some harrowing in this case.

Any tampering with the deep land carrying Aira caespitosa, or the Mixed Deep type of vegetation, is not advocated. This land is of more value to the grazing as it stands than under any class of herbage that might be introduced.

Molinia land is most susceptible to improvement. Something on the lines carried out by Mr. Allan, Auchenleck, Kirkcudbrightshire, and described by Young (73), would probably meet the case. The surface would require to be burned or cut over, manured, limed, and seeded with cleanings. The cost of such treatment is estimated to be about £3 : 10 per acre. As the improvement would last for 5 years, the annual charge would be 14/- per acre. If 20 acres were done, this would impose an annual charge of 11.2d per acre over the whole grazing, or 12.9d per ewe. The question may be asked, would the improvement of 20 acres, which after all represents only 6.7 per cent of the area, increase the value of all lambs, numbering 245, by at least 1/1 per head? When all things are considered, it probably would. It would require to be done, however, in strips in order to get the sheep spread out and prevent the fouling of the improved area. There is no doubt it would be of some value in counteracting pine disease.

If 40 acres were done over a period of years, would this add over 2/2 per head to the value of the lambs? This is problematical, but the project would be worth trying. It must be remembered that the soil under Molinia in this grazing is good, and its improvement would represent a considerable gain to the area. It would probably be best, however, to run the same number of stock as at present, not to increase it.

Stocking is already high, and the improvement of deep-land herbage would only partially relieve the high concentration on the sweet ground. The improvement of these Molinia areas would be equivalent to a slight reduction in the rate of stocking which would be all to the good. Along with mineral treatment for pine disease, it would make the changing of the flock unnecessary.

The improvement of hill-land lies entirely in the hands of the farmer. If he feels doubtful about future prospects in the industry, it is not likely that such projects will advance much beyond the experimental stage. On the other hand, he will more readily adopt measures by which nutrition and health can be improved by administering feeding materials direct to the stock rather than to the soil. In the East Borders and neighbouring districts, results of a spectacular nature are being obtained in this direction, at trifling cost. The experiments by which this has been brought about and by which the control of pine disease has been effected, now fall to be described.

Summary.

1. It is desirable that grassland surveys be more closely related to pastoral conditions in the areas dealt with.

2. A regular sheeps' grazing in the East Borders,

amounting to 292.589 acres, was surveyed in detail. A description is given of its botanical and pastoral status.

3. Suggestions are made regarding the improvement of this grazing.

EXPERIMENTS ON THE CONTROL OF PINE DISEASE.

16. THE EFFECT OF A MIXTURE OF MINERALS AND VITAMINS.

In order to ascertain the effect produced by a mixture of minerals and vitamins on sheep confined on pining land, an experiment was instituted in consultation with Professor Shearer, at Middlesknowes, Jedburgh, in November 1934. After the experiment was arranged, the Animal Diseases Research Association collaborated with the work and defrayed one-half of the cost.

In this experiment, 40 Cheviot ewe hoggs, which had been bred on the farm and which were intended to form part of the regular breeding stock, were divided into two groups of 20 each, and individually tattooed on the ear. They were put to graze on adjacent fields of rotation grass at an altitude of 800 feet. The soil was of a light shallow nature typical of the Andesite, and much addicted to pining. The hoggs were fed a basal ration of dried beet pulp, supplemented with hay when necessary. The test proper began on January 4th 1935. The feeding of the groups was as follows, per head per day.

Group (1) 4 ozs. Beet Pulp (molassed),
1 oz. Mineral and Vitamin Mixture.

Group (2) 4 ozs. Beet Pulp (molassed),
No Minerals or Vitamins.

The mineral mixture fed to Group (1) was -

36 per cent Crude Oxide of Iron

27 " Steamed Bone Flour

27 " Salt

10 " Arachis Oil (1250, Vitamin A, per c.c.)
(1250, Vitamin D, per c.c.)

All feeding materials used throughout the experiment were weighed and mixed by the writer. Each day's feed for each group was weighed up in separate bags. Owing to the mild winter and the confinement in the enclosed fields, the hoggs developed a tendency to scour. Plain beet pulp was therefore substituted for the molassed variety from January 25th onwards. The experiment terminated on May 18th 1935. Weighings were made periodically with the following results.

	Group I Mineral Group Average Weight lbs.	Group II Controls Average Weight lbs.
January 4th	60.08	58.42
February 21st	61.75	56.53
May 18th	79.45	76.27
	Increase 19.37	Increase 17.85

For individual weights see page 248.

The hoggs in the Mineral Group early established their superiority. Between January 4th and February 21st, 12 of them increased in live-weight, the average increase for the whole group being 1.67 lbs. per head. The Control Group, on the other hand,

showed an average decrease in weight of 1.89 lbs. during the same period. Only 6 of them showed an increase in weight.

On February 21st, the Control Group was considered to be on the verge of pining, which was confirmed when the results of blood tests taken on February 25th were made available. Owing to a heavy fall of snow at this time, however, it was deemed necessary to increase the feeding, and so the beet pulp allowance was raised from 4 ozs. to 6 ozs. per head, per day. Hay was also provided. This continued till March 7th. The control hoggs had by that time improved, the extra feeding having apparently staved off pining. This was unfortunate from the point of view of the experiment. Thereafter, there was no sign of the disease, and the experiment was discontinued on May 18th.

Throughout the test the Mineral Group were much superior. They were fresher and more active, and were much better than the farmer's own hoggs which were being wintered on roots, hay, and concentrates. They grew stronger in the bone than the controls, and were better developed in the head. Farmers who examined both groups in June valued the mineral hoggs at 3/- per head more than the controls. Thereafter they could readily be picked out in subsequent years from the rest of the flock. While the amount of minerals consumed was far greater than was found

necessary in subsequent experiments, the results showed that Cheviot hoggs can stand large quantities of this type of mixture without any undesirable effects.

Effect of Minerals on Scouring.

The mineral and vitamin mixture had a marked effect in reducing the amount of scour. The numbers affected in each group were recorded from time to time.

	Jan. 14th	Feb. 21st	March 21st	April 9th	May 3rd
Mineral Group	5	6	7	5	3
Controls	10	14	12	12	5

The Control Group had a greater number of scouring hoggs and more of them were badly scoured. They were in a weaker condition. One of them died in April. There were no deaths in the Mineral Group.

Blood Estimations.

In order to ascertain the condition of the blood in the two groups, samples of blood were taken from 6 sheep in each group on February 25th, 1935, by Dr. H. Dryerre. The results were :-

Mineral Group.		Controls.	
No.	Haemoglobin %	No.	Haemoglobin %
25	12.12	5	8.90
27	11.85	9	9.08
33	10.55	13	9.64
36	9.24	14	9.65
37	9.08	18	8.34
39	10.70	20	9.08

Mineral Group.	Haemoglobin %	Controls.	Haemoglobin %
Average	10.60	Average	9.11

This showed an appreciable difference between the two groups, the blood of the control hoggs being poorer in Haemoglobin by some 14 per cent.

Average figures for other blood constituents were :-

	Mineral Group. mg. per 100 c.c.	Control Group. mg. per 100 c.c.
Serum Calcium	9.4	9.25
Inorganic Phosphorus	5.2	3.5
Organic Phosphorus	5.4	4.5

There was therefore a marked difference in favour of the Mineral Group in both inorganic and organic Phosphorus. Serum Calcium showed little change.

Weight of Wool.

The wool from both lots was weighed at clipping time, but no appreciable difference was found. The average weight was 3.37 lbs. of washed wool from the mineral hoggs, and 3.47 lbs. from the control hoggs. There was apparently no check to the growth of wool during the course of the experiment.

While there was a striking difference in the appearance of the two groups of sheep, the main purpose of the experiment was not fulfilled. Pine disease did not actually develop.

Summary.

1. The feeding of a mineral and vitamin mixture to hoggs enclosed on pining land was markedly beneficial to health and growth. The condition of the blood was improved.

2. The use of concentrated food in the form of beet pulp, at the rate of 4 - 6 ozs. per head per day, appeared to act as a preventive of pining. The belief of farmers in the efficacy of concentrated foods for this purpose receives support from this experiment.

3. In experiments designed to ascertain the cause of pine disease, the use of concentrated foods should be discarded.

17. EXPERIMENTS WITH IRON COMPOUNDS ON EWES.

As the mineral mixture used in the previous experiment had produced marked effects upon the health and vigour of sheep on pining land, it was resolved to carry out further tests to see whether the cause of pine could be attributed to a deficiency of any one of these minerals, or elements associated with them. As iron is of importance in the treatment of anaemia, it was arranged to conduct tests with iron compounds.

1. Iron and Ammonium Citrate.

In the summer of 1935, an outbreak of pining occurred among ewes at Middlesknowes. Two groups of four ewes were drawn out and individually marked. One of the groups was given iron and ammonium citrate at the rate of 3½ gms. per head daily for one week, and every second day thereafter for two weeks. The iron salt was administered in the form of a liquid dose made up with an equal quantity of water. The other group received no treatment. Both groups were enclosed on grass fields of a pining nature. The sheep had been pining for some weeks and were in an emaciated state. Most of the lambs were also affected, as will be seen from the accompanying photograph.

Treatment began on June 8th, 1935. There was little change during the first ten days. Within a

June ~~July~~ 1935.

Healthy Cheviot Ewes and Lambs.

Pining Cheviot Ewes and Lambs used in this experiment. June ~~July~~ 1935.
Note listless carriage, eyes partially closed, sunken wool; lambs wasted and pining.

fortnight, however, there was a definite turn for the better, and within three weeks all pining symptoms had gone. The lambs also recovered and made satisfactory progress. On the other hand, the Control Group showed no improvement either in the ewes or in the lambs. A comparison of the weights of both groups was as follows.

Treated Group.			Controls.		
No.	June 13th lbs.	July 3rd lbs.	No.	June 13th lbs.	July 3rd lbs.
1	73	90	2	59	68
3	77.5	87	4	52	57
5	68	68	7	94	97
6	61	66	8	66	68
Average	69.87	77.75		67.77	72.5
Increase ... 7.88 lbs.			Increase ... 4.73 lbs.		

It will be seen therefore that the Treated Group made a considerable increase in live-weight. The Controls also increased, probably due to the fact that they were on rather better pasture.

Blood tests carried out by Dr. H. Dryerre showed the following results.

Treated Group.			Controls. (untreated)		
	Haemoglobin %.			Haemoglobin %.	
No.	June 6th	July 3rd	No.	June 6th	July 3rd
1	11.0	10.3	2	8.7	7.7
3	4.5	9.3	4	11.0	5.9
5	7.3	7.8	7	-	8.6
6	9.1	9.1	8	-	7.0
Average	7.97	9.12		-	7.3

From July 3rd onwards, the Untreated Group were given doses of iron and ammonium citrate as above described. The animals made a satisfactory recovery from the disease in about three weeks. The weights recorded on July 3rd and on July 19th when recovery was well under way, were as follows.

No.	July 3rd lbs.	July 19th lbs.
2	68	79
4	57	66
7	97	109
8	68	85
Average ...	72.5	84.75

The average increase was 12.25 lbs. Ewes Nos. (2) and (7) were clipped before the last weighing, but this is not taken into account.

The recovery in weight gives some idea of the emaciated condition of the sheep in their original pining state. As a matter of interest in this connection, it may be stated that 8 healthy ewes were run off the hill and weighed on June 13th, and their weights compared with the 8 pining ewes. The average weights were :- 86.8 lbs. for the healthy ewes, and 68.8 lbs. for the pining ewes, - a difference of 18 lbs. per head.

2. Iron and Ammonium Citrate and Crude Oxide of Iron.

A group of 20 pining ewes and 20 lambs were used in a further experiment at Middlesknowes. They

were given four daily doses of iron and ammonium citrate, and thereafter received 4 ozs. of beet pulp and ⅓ oz. of crude oxide of iron per head per day. These quantities were increased by 20 per cent to allow for the lambs. No salt was added. The test began on 5th July, 1935. Within a fortnight there were marked signs of recovery, and by July 28th recovery was considered to be complete. The lambs began to mend even before there were visible signs in the ewes.

3. Crude Oxide of Iron.

On July 22nd, 1935, 5 pining ewes with lambs were taken off the hill and given 4 ozs. of beet pulp and ⅓ oz. of crude oxide of iron per head per day. A little extra was added for the lambs. As the ewes had been accustomed to eat concentrates as hoggs, they readily took to the box feeding. Recovery was rapid. They were put back to the hill cured, 21 days after treatment commenced.

The percentage composition of the crude oxide of iron used in these tests was - Fe_2O_3, 58.51; Al_2O_3, 16.95; SiO_2, 7.93; TiO_2, 7.65; MnO, 0.14; CaO + MgO, 0.9; Na_2O, 5.75; As_2O_3, 0.008; Loss on ignition, 2.57. This was the composition supplied by the makers.

Since these early experiments were carried out, a large number of pining sheep have been successfully

treated by the writer either with iron and ammonium citrate or crude oxide of iron. A total of 193 pining sheep have been dealt with (not including lambs), of which 184, or 95.4 per cent, recovered. The practice has been widely adopted by farmers in the district. It is found that the cure remains effective for many months.

In order to test the possibility of keeping sheep on pining land without a change for a protracted period, 16 ewes at Middlesknowes were individually ear-marked and retained on their regular grazings for two years, namely, from October 1935 to October 1937. Courses of crude oxide of iron were given in place of the usual changes. Three of these ewes were pining when treatment began. All sheep remained in a healthy and thriving state throughout the period.

Crude oxide of iron has been found very effective as a preventive of pine disease as well as a cure. It is now largely employed for this purpose. It will be sufficient here to give the results of tests conducted by the writer on hill hefts on three different farms. A mixture composed of equal parts of crude oxide of iron and salt, without any other material, was put out in boxes on hill land from January to May. The disease among ewes in summer thereupon almost entirely disappeared. The results are set out below. A comparison is made with previous years when no treatment was given.

FARM (1).
(260 ewes)

		No. of Piners
1934	No mineral used	25
1935	No mineral used	32
1936	Treated	none
1937	Treated	4

FARM (2).
(180 ewes)

		No. of Piners
1935	No mineral used	12
1936	Treated	none

FARM (3).
(110 ewes)

		No. of Piners
1936	No mineral used	5
1937	Treated	none

Summary.

1. Iron compounds are of specific value in curing and preventing pine disease in the East Borders.

2. Crude oxide of iron is as effective in practice as iron and ammonium citrate.

3. Improvement in the condition of pining sheep was noticeable in 10 - 14 days. Recovery was complete in about 21 days.

4. Ewes treated periodically with iron compounds have been kept on pining land for two years without a change.

5. The disease has been largely abolished where iron compounds have been used as a preventive.

18. EXPERIMENTS ON HOGGS WITH IRON AND COPPER COMPOUNDS.

In 1935, it was felt necessary to arrange a large-scale controlled experiment in order to test thoroughly the value of iron compounds. It was also desirable to know what part, if any, was played by copper in the etiology of pine. Minute traces of copper are usually present in iron salts. An experiment was accordingly arranged at Middlesknowes. The whole of the work, with the exception of blood sampling, was carried out by the writer.

60 "top" Cheviot wether hoggs which had been bred on the farm, and which had no visible symptoms of pine about them, were divided into two groups of 30 each and put to graze on Peg Law, which is much affected with the disease. Both groups ran together throughout the experiment and received no feeding of any description except what they could pull. The conditions between the two groups were therefore practically identical. All the animals were separately numbered with ear tags. Treatment began on 19th August as follows :-

Group (1) Treated with iron and ammonium citrate.

Group (2) No treatment.

The administration of the iron and ammonium citrate was on similar lines to that already described, 49 gms. being given over a period of three weeks.

Effects of Iron Treatment.

In spite of the excessive handling to which they were subjected, the dosed group made steady progress. Two of the hoggs, however, died of Braxy. Two hoggs developed symptoms of pine in October, but recovered when given additional doses. Thereafter, all animals in the group remained entirely healthy though they remained on pining land without any supplementary feeding from August till February, a period of six months.

The control group, on the other hand, began to show signs of the disease within a few weeks. This gradually spread until all but four animals were affected. There were 4 piners in September, 13 in October, 26 in November, and 26 in December. The incidence, therefore, was ultimately 86 per cent. They exhibited all the usual symptoms of the malady and several of them got so weak and emaciated that they were on the point of collapse. This part of the experiment was accordingly discontinued on December 7th.

Ten of the pining control hoggs were thereafter treated with iron and ammonium citrate on the lines already described. In spite of the severe nature of the weather and the fact that all artificial feeding was withheld, they made steady progress and werewall recovered within 5 weeks. These hoggs presented the phenomenon of steadily losing condition

and at the same time rapidly improving in health. The food shortage on the hill land was acute. They lost on the average 9.83 lbs. between December 7th and February 6th. Eye colour, however, improved from 30.4 to 33.1 over the same period.

The average weights recorded during the main experiment were as follows :-

	Aug. 22nd	Sept. 12th	Oct. 26th	Nov. 21st	Dec. 7th
Treated Group	46.2	48.7	58.7	58.5	59.4
Controls	46.4	48.2	55.0	55.1	55.4

Increase.	lbs.
Treated Group	13.2
Controls	9.0

A complete record of the weighings is given in Appendix IV, page 249.

It might have been expected that all pining hoggs would have lost weight. This was not so. Those that had only a mild attack retained their appetite and so continued slowly to increase.

Haemoglobin.

Samples of blood were taken by Dr. Dryerre from 5 hoggs in each group on November 5th. The average results were :-

	Nov. 5th Haemoglobin %.
Treated Hoggs	10.64
Pining Hoggs	8.34

Untreated Group.
Decr: 16th 1935.

Janr: 18th 1936. Hoggs treated with iron and ammonium citrate, including some of the above group. All hoggs were confined on pining land since August. Note bold bright appearance and clean faces.

There was a lower Haemoglobin value in the blood of the pining hoggs in all cases. On December 9th, blood from the remaining hoggs in each group was tested, not including the healthy hoggs in the pining group. For blood figures see Appendix V, page The average figures were :-

	Dec. 9th Haemoglobin %
Treated Hoggs	10.2
Pining Hoggs	9.6

There was not always a clear-cut difference. Many of the pining hoggs appeared to have a Haemoglobin value little below normal. Ten of them had 10 per cent of Haemoglobin or over. These usually had only a mild form of the malady.

There was a close correspondence between Haemoglobin content and live-weight. This is shown below.

	Haemoglobin %	Average Weight Dec. 7th lbs.
Very badly pined (10 hoggs)	8.5	47.6
Badly pined (6 hoggs)	9.7	57.83
Slightly pined (10 hoggs)	10.13	58.3
Healthy (4 hoggs)	not tested	64.2

Colour of Conjunctiva.

Records were made during the experiment of the degree of redness in the lining membrane of the lower eye-lids. The colour-scale shown on page 41

DECEMBER 16th 1935.

Pining Hogg No 947.

Note the listless and weak appearance.

JANUARY 18th 1936.

Hogg No 947 recovered from pine, one month after treatment with iron and ammonium citrate.

was used for the purpose. The average comparative figures on December 7th were :-

Treated Group	31.2
Control Group	29.4

There was a fairly close agreement between the individual readings and the percentage of Haemoglobin as ascertained by Dr. Dryerre. Individual figures are given in Appendix V, page 250.

Temperature of Hoggs.

In order to find whether there was any difference between the groups, the temperatures of all the hoggs were taken on December 7th. Individual figures are given in Appendix V, page 250. The average results were :-

Treated Group	104.27° F.
Control Group	104.84° F.

There was no evidence of any febrile disturbance even among the worst pining hoggs.

Effects on Wool Growth.

Approximately six months after the experiment began, namely, on February 6th, observations were made on the winter growth of wool in both groups. The results showed a moderate increase in the Treated Group but a much smaller increase in the Control Group. The data recorded were :-

	Wool. Winter growth. cms.	No. of Stops in wool.
Treated Group (average of 27)	1.75	7
Controls (average of 25)	1.4	17
Farmer's Ewe Hoggs (average of 40)	3.3	9(slight)

The Treated Group, therefore, grew 25 per cent more wool than the untreated. As four of the worst of the untreated hoggs had been removed to Moredun and were not included in the above measurements, the difference between the groups must have been actually greater. Many of the control hoggs had such severe stops in the wool that they would probably cast their fleeces in early summer.

The farmer's own hoggs had received their usual change to lowland pastures in August, followed by wintering at home on roots and concentrates. They naturally did much better than the experimental hoggs, which during the latter part of the experiment were on a starvation diet. The slight stop in the wool of some of the farmer's hoggs was due to a check in December.

Pining in relation to live-weight.

An examination of the data recorded in this experiment brings out a definite correlation between the incidence of pine disease in hoggs and their live-weight. The points are summarised below.

(1). In the Treated Group, the only two hoggs which

developed pine (though afterwards cured) were the smallest hoggs in the group.

(2). The two smallest hoggs in the untreated group were among the first to show symptoms of the disease.

(3). Of 13 pining hoggs on October 26th, 10 had been below the average weight of the group at the commencement of the experiment.

(4). The four hoggs of the untreated group which never developed pine were all above the average weight of the group, and included two of the three heaviest hoggs in the group.

The first record of individual weights was taken on September 12th. Ear tags could not be inserted before this owing to flies.

It seems clear from this experiment that small hoggs in any section of the flock are more liable to pine than those which are stronger and better developed. The experimental animals were "top" hoggs and were, therefore, further removed from any bias towards pining at the commencement of the experiment than any other groups which could have been selected.

EFFECTS OF COPPER.

As copper is known to be of value in the metabolism of iron in the animal body, an experiment was arranged to ascertain its effects on pining sheep.

Eleven pining hoggs from the control group already mentioned were used for this test.

As the iron and ammonium citrate which had been used so successfully contained 0.001 per cent of copper, and as 49 gms. of the iron salt had been administered, the amount of copper ingested was approximately 0.5 milligrammes. It was decided to give each of the pining hoggs ten times this quantity of copper, namely, 5 milligrammes, in the form of copper sulphate dissolved in distilled water. Treatment was given in 14 doses over the period December 11th to December 31st, 1935. The hoggs continued to run on Peg Law.

There was never at any time any improvement in the state of these hoggs. Instead of making progress like the group which was being treated with iron and ammonium citrate during the same period, they rather tended to pine worse. They lost more weight than that group, and the colour of the conjunctiva fell to still lower levels. A comparison of the conjunctiva readings is given below.

	Iron and Ammonium Citrate Group.	Copper Group.
I935		
December 7th	30.4	32.0
I936		
January 15th	33.1	26.0

Fuller details are given in Appendix VI, page 251.

It was apparent, therefore, that the administration of copper had entirely failed to produce any effect upon the pining condition. These hoggs thereupon were put on to iron and ammonium citrate, when they slowly recovered. They continued all the time on Peg Law. The average colour of the conjunctiva rose from 26.0 on January 15th to 31.8 on February 6th. The live-weight, however, still further declined owing to the severe weather and the absence of suitable food.

Discussion.

It was established by these tests that pine disease is a form of nutritional anaemia which can be cured and prevented by the administration of iron salts. It appears, therefore, to have a close similarity with bush sickness in New Zealand, enzootic marasmus in Western Australia, and pining diseases in some other countries. These conditions also usually yield to treatment with iron compounds.

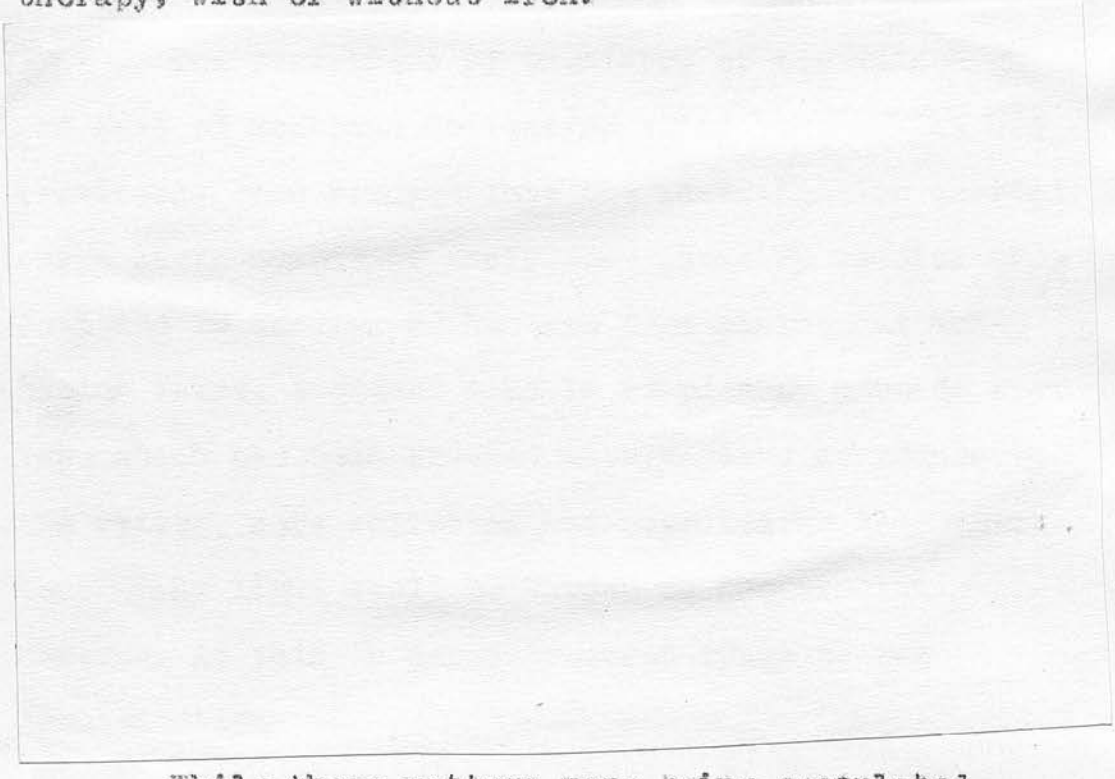
The precise rôle of iron in the present case, however, was not clear, for several reasons. Godden and Grimmett (25) have shown that pining soil from the East Borders contains large quantities of available iron. It could also be seen that the land on which the hoggs in the experiments just described were confined had no lack of iron, as considerable amounts of hydrated oxide of iron could be observed in

the drainage water. Underwood (74) had shown at this time that the liver, kidney, and spleen of sheep affected with enzootic marasmus have a higher concentration of iron than normal sheep. The animals examined had no difficulty in absorbing ample quantities of iron from the food, but the utilisation of the iron was defective. He concluded that enzootic marasmus was not due to iron deficiency. It seemed as if pine disease in the East Borders might possibly be in the same category.

If any mineral substance were responsible, it appeared probable that some of the trace elements in the iron compounds used might furnish a clue. This possibility was strengthened by the fact that in practice a change of pasture for three weeks is usually sufficient to serve as a preventive of the disease for many months. Further, it had been found in the experiment with 30 treated hoggs that the normal dosage of iron had not been sufficient in the case of two of the hoggs to prevent the onset of the malady. Additional doses, however, had had the desired effect. It seemed unlikely in this instance that the extra amount of iron given to the animals was responsible for the result, as the quantity already consumed was very large.

The possibility of copper being a responsible factor had been duly tested on Peg Law, but the findings were entirely negative. This test had shown,

however, that pine disease is different from "salt sickness" in Florida which Neal and Becker (32), quoted by Orr, have shown to respond to copper treatment in the presence of iron. It also demonstrated that "lecksucht" in Holland (27) is in a different category from pine as the condition responds to copper therapy, with or without iron.



While these matters were being speculated upon, attention was drawn to reports of work carried out in 1934 in Western Australia (75), and in New Zealand (76), in which iron-free extracts of hydrated oxide of iron, or limonite, had been found to cure the form of the disease in those countries. The use of cobalt had been tested in South Australia (77) with favourable results on two sheep. Tests with cobalt, manganese, nickel, and zinc were later conducted in some detail in Western Australia (78),

as a result of which cobalt was found to give positive results.

Many of these tests, however, had been carried out with single sheep or groups of two sheep. An experiment with seven sheep was employed in one of the final tests at that period in Western Australia, but there was no corresponding control group. It was therefore difficult to know what the precise significance of these experiments might be. While these findings were of much interest, the exact cause of pining in the East Borders remained undetermined.

Summary.

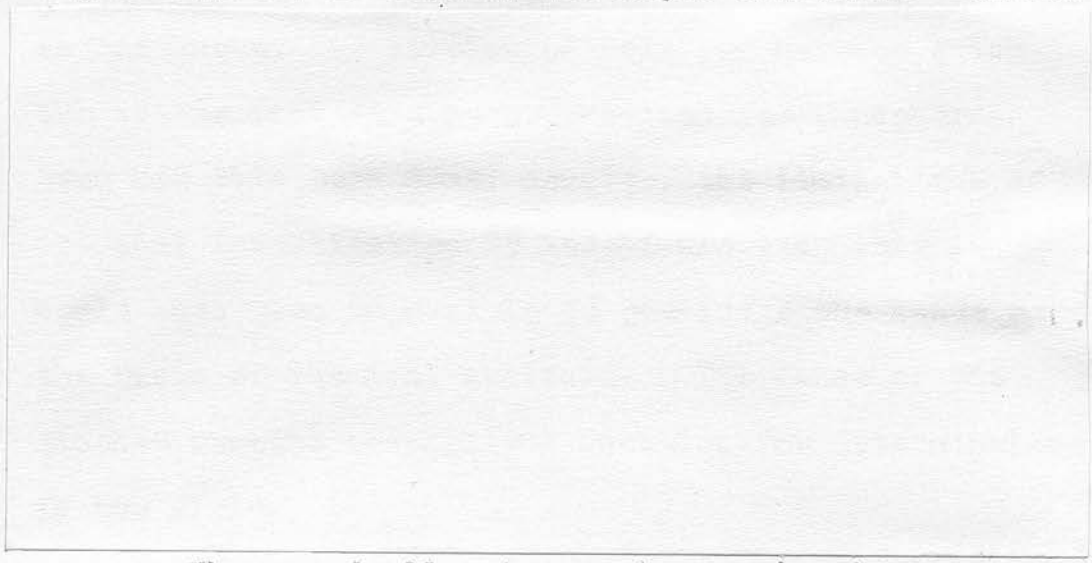
1. Pine disease is a form of nutritional anaemia which can be cured and prevented by the administration of iron salts.

2. The administration of copper has no curative effect upon pining sheep in the East Borders.

3. The anaemia in pine disease is different in nature from "salt sickness" in Florida and "lecksucht" in Holland. Both of these conditions are reported to respond to copper.

19. THE INFLUENCE OF PHOSPHORUS.

While there was a possibility that pine disease might be controlled by one or other of the minor nutritional elements, the writer felt it desirable in the meantime to test the effect of an element which oulks largely in the nutrition of stock, namely phosphorus. It seemed unnecessary to attribute pine disease to some obscure cause without first determining the effect of some of the major elements. So far



These and all subsequent experiments were carried out independently by the writer, the whole expense being borne by him.

There were several reasons which suggested that phosphorus might play an important part in increasing the resistance of animals to the malady if not as a direct cure. These are summarised as follows.

1. The feeding of any form of concentrated food to sheep on pining land is believed by farmers to

prevent pine disease. The phosphorus content of grains and seeds is usually high.

2. The fact that young growing sheep are more susceptible seemed to indicate a connection with some of the bone-forming elements.

3. Experience in the district, notably at Stotfield, Edgerston, had shown that manuring the hill land with Ground Mineral Phosphate had a considerable influence in reducing the incidence of pine.

4. The blood of pining sheep and cattle frequently shows a low content of phosphorus.

While much of this evidence was indefinite, it did seem at least to justify some effort at exploring the question. Accordingly, tests were arranged at Middlesknowes in the summer of 1936.

Preliminary test with Phosphorus.

A preliminary test was carried out with 4 pining ewes, and 4 pining lambs which had been previously taken off their mothers. All sheep were confined on pining land and got no supplementary feeding. Treatment began on July 17th, 1936. Particulars of treatment were :-

Material used. Crystalline di-sodium phosphate - Na_2HPO_4, 12 H_2O.

Dosage. Ewes - 2 gms. per head per day.
Lambs - 1 gm. per head per day.

No. of Doses. 17 doses spread over 3 weeks.

Within a fortnight, a visible improvement was noted, though it was more apparent in the ewes than in the lambs. The improvement continued, and, with the exception of one lamb, which died, all sheep were well recovered by the middle of August. They continued to go on satisfactorily thereafter.

Experiment with Phosphorus on Hoggs.

It was arranged to conduct a controlled experiment with phosphorus on a fairly large scale, commencing in August 1936. Forty Cheviot hoggs, bred on the farm, were employed, and these were put to graze on Peg Law, which had been used for the tests in the previous year, already referred to. The hoggs were divided into the following groups.

Group I - 20 hoggs; dosed with 2 gms. per day of crystalline di-sodium phosphate, made up in distilled water; 17 doses given per sheep, August 7th to August 28th, 1936.

Group II - 20 hoggs; no treatment.

The di-sodium phosphate was of B.P. standard, the limits for arsenic and lead being 0.0005 per cent in each case. Two samples of the salt were specially tested for cobalt by Dr. J.F. Tocher, Aberdeen, but were found to contain no trace of this element.

The hoggs represented part of the second draw of lambs and were therefore not quite so strong as those used in the previous year. Five pining hoggs were included in each group, two of them in each group

being much affected with the malady. The dosed group started at a disadvantage, being lighter in weight on the average. They also had rather the worst affected hoggs, one of them dying a week after the experiment began.

At the end of the dosing period, the treated hoggs looked worse and seemed to have got a check. However, within two weeks of the cessation of the daily handling and dosing, they rapidly improved and continued thereafter to go forward. Two of the hoggs which had been pining died, but the remaining piners in the group steadily recovered.

The untreated group began to go back in September, one of them dying during the month. There was a considerable increase in pining in the group. On September 28th there were 15 pining hoggs, making an addition of 10 piners in the group since the experiment began. Four of the hoggs, however, remained entirely healthy.

The average weights recorded during the period are set out below. Details are given in Appendix VII, page 252.

	Aug. 7th	Sept. 28th	Increase
	lbs.	lbs.	lbs.
Treated Group	35	40.3	5.3
Untreated Group	36.2	39.68	3.48

The colour of the conjunctiva on September 28th was :-

PEG LAW, JEDBURGH.

The main experimental station where the causes of pine disease were worked out.

Treated Group 35.7

Untreated Group 33.1

Details are given in Appendix VII, page 252.

There was a marked contrast between the groups on September 28th. The treated group were all improving and mending, while the majority of the untreated group were going the other way. They could readily be picked out by the dark and sunken appearance of the wool and the dark unhealthy colour of the face. It was felt unnecessary to continue this stage of the experiment any further, and accordingly treatment was given to the control group.

The control group were given the same material as before, except that 5 gms. of di-sodium phosphate were administered, per dose, instead of 2 gms. This was done because the opinion had been formed that doses of 2 gms. were rather small for curative purposes. 17 doses were given. There was clear evidence of the improvement of the pining hoggs. Within 12 days they began to change for the better, and by October 21st all pining symptoms had gone. Their faces cleaned up, their bellies filled out, the wool began to rise, and there was a marked gain in vitality. There was an appreciable change in conjunctiva value. The curative effect was much more rapid and pronounced than in the case of the pining hoggs in the original group, no doubt owing to the larger doses given. It was apparent from these tests

that di-sodium phosphate was just as effective as iron and ammonium citrate.

While most of the hoggs were sold at the end of october, one hogg of the originally treated group and five hoggs which had been treated in the control group were retained on Peg Law till the end of December. No feeding was supplied. They all remained in a vigorous and healthy state throughout. The following particulars were recorded of these hoggs.

	Live-weight	Conjunctiva	Increase in wool
1936	lbs.		cms.
October 1st	37.7	30.8	-
December 8th	41.6	36.8	1.7

These hoggs remained on the farm for one year without a change, namely, until September 1937. They showed no signs of pining.

In the following year, a test was conducted on pining hoggs at Swinside Townhead. Di-sodium phosphate B.D.H., A.R., was used in this case. All hoggs were in an advanced stage of the malady, nevertheless, the treated group made steady progress while the controls showed no improvement.

Results from the use of Phosphorus in practice.

The influence of Phosphorus compounds in preventing and curing pine disease in practice was tested on a fairly large scale on several farms by the feeding of Steamed Bone Flour, along with an equal

weight of salt. No concentrates or other minerals were given. The material was weighed out by the writer and a record was kept by him of the amount consumed by the sheep on Farms A. and B. mentioned below. The shepherds estimated that 95 per cent of the animals ate the mixture. In all cases it had a marked effect in reducing pine disease and in improving the condition and thriving capacity of stock on pining land.

FARM A.
(180 ewes)

		No. of Piners
1935	No mineral used	30
1936	No mineral used	26
1937	Treated	4

Amount of mineral consumed.
(Nov. 22nd, 1936 - April 5th, 1937)

	per head ozs.
Steamed Bone Flour	7.5
Salt	7.5

FARM B.

		No. of Piners	
		Ewes	Lambs
1937	Untreated (320 ewes)	20	30
1937	Treated (300 ewes)	6	2

Amount of mineral consumed.
(Jan. 14th - July 1st, 1937)

	per head ozs.
Steamed Bone Flour	7.9
Salt	7.9

The land on which the two groups of ewes on Farm B. were running was not reckoned to be much different as regards pining. Judging from Sale results, the shepherd estimated the value of the treatment to be at least 1/- per lamb. The cost of the treatment, including feeding boxes, was 0.8 pence per ewe.

FARM C.

(62 ewes; 20 hoggs)

		No. of Piners
1935	No mineral used	1
1936	No mineral used	1
1937	Treated	none

The opinion was formed that Steamed Bone Flour was little behind crude oxide of iron as a preventive of pine disease in these experiments.

Discussion.

To what extent the effect produced by the administration of phosphorus in curing and preventing pine disease in these experiments was due to some trace elements present in the compounds is not known. There was no trace of cobalt in the di-sodium phosphate. This was definitely established. Work on enzootic marasmus suggests that neither arsenic, lead, nor sulphur, in minute amounts, have any effect upon the course of the malady, though no similar work had yet been done on pine. The possibility of sodium and

chlorine having any direct influence is unlikely. The feeding of common salt to hill sheep is a regular practice on many pining farms, but it has never been found that this exerts any control upon the disease. Di-sodium phosphate may have had some slight effect on stomach worms. In a controlled test with 40 lambs carried out by the writer in 1937 on a lowland farm much troubled with stomach worm, it was found, however, to have no value. In any case, there are no appreciable vermicidal properties in Steamed Bone Flour and salt. It remains, therefore, at the present stage to consider phosphorus only.

J. Stewart (79) has shown that when the phosphorus level of the diet of sheep ranges from 1 to 1.5 gms. of phosphorus per day, which is comparable, he states, to that of sheep on many of the hill farms of Yorkshire and Northumberland, a typical picture of phosphorus deficiency is demonstrable by the chemical examination of blood and bones. In Stewart's experiments, no effect was produced on digestion by a low phosphorus level in the diet, but the utilisation of the food was defective. The sheep in the tests averaged 75.5 lbs. per head. The daily intake of phosphorus in the experiments described in this thesis is not known. It was found, however, that the administration of 0.173 gms. phosphorus per day for 17 days was sufficient to prevent the occurrence of the disease in hoggs weighing around 38 lbs. The

giving of 0.432 gms. phosphorus per day for 17 days cured the condition, although cures were made with half this quantity. The treatment was effective for many months. In the light of Stewart's findings, it seems reasonable to conclude that these sheep were suffering from a lack of phosphorus. The disease known as "Cappy" or "Double Scaup", however, (80,81), is not present in the East Borders.

The blood of sheep in pining country often shows a comparatively low level of phosphorus (see page 189). Blood calcium is sometimes even more deficient according to the results of Stewart and Piercy (51). Auchinachie and Fraser (82) have demonstrated that a reciprocal relationship exists between calcium and phosphorus in the blood. When phosphorus is low, calcium is often relatively high, due to the utilisation of bone substance and the release of additional calcium in the circulation. While this condition is present to some extent in the blood of pining sheep examined by Stewart and Piercy (51), it is liable to considerable variation and suggests that both elements may sometimes be lacking, and may therefore both contribute to the anaemia. Orr (31) has pointed out that malnutrition or a defect in the metabolism arising from any cause tends sooner or later to be associated with anaemia.

The effect of phosphorus was tested in connection with bush sickness in New Zealand. Aston (83)

found that cattle could be kept on land treated with phosphatic manures for about 12 months after animals on untreated ground had died of the disease. No benefits were obtained, however, from the use of medicinal phosphates. The theory of phosphorus deficiency in connection with bush sickness was thereupon discarded. It would have been interesting, however, if this aspect had been further explored.

It has already been noted in these experiments and has been referred to by writers in Australasia that pining sheep in the early stages may show no appreciable reduction in red cells, or haemoglobin, even though symptoms of the disease may be well marked. This suggests that some factor may be responsible for the initial disturbances and that the anaemia proper follows at a later stage. It is suggested that an insufficiency of available phosphorus may be one of the factors involved.

Summary.

1. The administration of phosphorus acts as a cure and preventive of pine disease.

2. The curative properties of small quantities of phosphorus appear to hold good for many months.

3. Experimental evidence suggests that an insufficiency of phosphorus is one of the predisposing causes of the malady.

20. THE EFFECTS OF COBALT.

From the results of research work carried out in Australia and New Zealand, it seemed probable that the beneficial results obtained from the use of iron compounds in the Cheviot region might be due to the presence of cobalt. A sample of the crude oxide of iron which had proved of value in some of the experiments described in this thesis was tested for the writer by Dr. J. F. Tocher, Aberdeen. It was found to contain "not less than 50 parts per million of Cobalt". It was accordingly arranged to explore the possibilities of this element by a series of tests conducted in 1937.

Preliminary tests with Cobalt.

In May 1937, three badly pined Cheviot ewes were confined on a piece of pining hill land at Middlesknowes. They were given doses of 3 milligrammes of cobalt per head in the form of cobalt chloride (B.D.H.; A.R.) in distilled water. 12 daily doses were administered over a period of three weeks. Within ten days an improvement in the general appearance and vigour of the sheep was noted, and within three weeks recovery was reckoned to be complete. All ewes nursed lambs throughout the test and these also improved along with their mothers. The progress of these ewes may be judged from the undernoted data.

1937	Average Weight lbs.	Average Conjunctiva
May 8th	70½	25
May 25th	79½	35.6

The average increase in weight amounted to 9 lbs. per head, while there was a marked rise in the colour of the conjunctiva. The ewes made good progress thereafter throughout the summer.

As 3 mg. of cobalt per dose appeared to be very effective, a test was arranged at a later date to find the effect of a smaller quantity. On a pining farm some three miles distant from Middlesknowes, 5 pining hoggs and 1 pining ewe were given 1 mg. cobalt per head per day during August. A similar group of pining hoggs was given iron and ammonium citrate in the manner already described. Treatment was continued over a period of three weeks. Both groups were completely recovered by the end of the period.

The Administration of Cobalt by Injection.

A pining ewe was confined on Peg Law for a period of 31 days. Three intra-muscular injections of cobalt chloride were given as follows :- (1) 8 mg. Co. on May 18th; (2) 12 mg. Co. on June 1st; (3) 12 mg. Co. on June 11th. The ewe made a gradual recovery. Between May 18th and July 19th the live-weight improved from 75½ lbs. to 84 lbs., while the colour of the conjunctiva rose from 37 to 40.

Improvement, however, was slower than in the case of the ewes which had been dosed by the mouth.

A similar test was conducted with three pining ewes on Peg Law over the period June 1st to June 19th, 1937. Two injections were given, each amounting to 12 mg. Co. per head, with a ten day interval. There was an average increase in live-weight of 8.5 lbs., but there was no change in the colour of the conjunctiva. The ewes improved for a time, then looked worse, but thereafter went ahead again. The rate of progress, however, was too slow. Accordingly they were given liquid doses of 3 mg. Co. per day. Within five days, they were in a fully vigorous and thriving state.

A controlled experiment on the above lines was carried out on a neighbouring farm. Injections were given to six ewes. Here also the rate of recovery was slow. One ewe died. As the controls registered a somewhat similar degree of progress, this experiment was discontinued.

The injection method for the cure of pining sheep held out the possibility of saving labour and undue handling, but it was not satisfactory. Progress was slower than by dosing. The disadvantage is that ewes might get down too far in the interval, resulting in a set-back to the lambs owing to a falling off in the milk yield. A rapid cure is essential. The quantities of cobalt injected at one

time, namely, 8-12 mg. Co., appeared to be well within the capacity of the animals, but 8 mg. seemed preferable. Smaller amounts than 8 mg. were not found to be more effective. The upper limit appeared to be somewhere below 20 mg. at one injection. This was given to 5 pining ewes not previously referred to, but while four of them made progress one of them died.

On the other hand, it seems probable in view of results referred to later, that pine disease might be prevented by giving one injection of cobalt. Protection would presumably be conferred for many months. No tests, however, have so far been made on this point.

Experiments with Cobalt on Hoggs.

Twenty Cheviot hoggs which were healthy and free from pine disease were divided into two groups on August 16th, 1937, and put to graze together on Peg Law, Jedburgh. The hoggs had been bred on the farm. Peg Law, as already noted, is much affected with pining. Treatment was as follows :-

Group (1) 10 hoggs; 1 mg. cobalt per day, for 14 days.

Group (2) 10 hoggs; no treatment.

Cobalt was given in the form of cobalt chloride (B.D.H.; A.R.) made up in distilled water. The 14 doses were spread over three weeks.

The treated hoggs made good progress and

remained entirely healthy. The controls, on the other hand, soon began to show symptoms of the disease. While all were healthy on August 16th, 8 out of 10 were pining by September 11th, and by the end of September only 1 hogg remained in a healthy state. The average live-weights of the hoggs were as follows.

	Aug. 16th	Oct. 5th	Increase.
	lbs.	lbs.	lbs.
Treated Group	38.35	46.25	7.9
Controls	36.4	39.0	2.6

The average conjunctiva readings were :-

	Aug. 16th	Oct. 5th	Stops in wool. (Dec. 9th)
Treated Group	34.1	36.9	2
Controls	37.0	33.7	7

Details are given in Appendix (8), page 253.

The treated hoggs increased by 7.9 lbs. per head, while the controls gained only 2.6 lbs. The colour of the conjunctiva rose in the case of the treated group, but fell in the case of the controls. It was clearly shown by this controlled test that the administration of 1 mg. cobalt per day for 14 days had entirely prevented the onset of pining.

The procedure next followed was to dose the control group, all of which, with the exception of one, were now affected with the disease. It was decided to attempt a cure with doses of $\frac{1}{2}$ mg. cobalt per head per day. Accordingly a total of 14 doses were given

at this rate, spread over three weeks, commencing on October 5th. All hoggs remained on Peg Law. By October 21st there were marked signs of improvement in the majority of the group, and within one month they were all recovered except two which had been very badly pined. These were given 5 additional doses of 3 mg. cobalt per day, after which recovery rapidly ensued. The hoggs remained on Peg Law till December 9th and made steady progress. One hogg, however, died in November. The following observations were noted.

1937	Weight. lbs.	Conjunctiva.
Oct. 5th	39.0	33.7
Dec. 9th	42.6	38.8

Details are given in Appendix (8), page 253.

Owing to a heavy fall of snow, all hoggs had to be removed from Peg Law on December 9th, but they continued to run on pining land until February 15th. No concentrates of any kind were fed. They were given hay, the produce of pining land. The group which had originally been treated in August remained entirely healthy throughout. This experiment, therefore, demonstrated that the administration of small quantities of cobalt over a period of three weeks will enable sheep to be maintained on pining land in a healthy state for at least six months.

Results from the use of Cobalt in practice.

1. An outbreak of pining occurred on a hill farm during September 1937 in which some 40 ewe-hoggs were involved. Treatment was administered by giving 1 mg. cobalt per head per day mixed with salt, together with a little concentrated food. A few of the hoggs were disinclined to eat out of the boxes and so were dosed by the mouth. All the animals recovered.

2. Cobalt was used as a preventive on a large scale during the winter and spring of 1937-38. The whole of the stock on a pining farm, numbering 550 ewes and hoggs, were given access to a mineral mixture composed of equal parts steamed bone flour and salt, with a small amount of cobalt added. The material was mixed and weighed by the writer, sufficient cobalt chloride being sprayed on the mixture to allow 40 mg. cobalt per sheep during the period January 1st to April 30th, 1938. The treatment was entirely satisfactory. There was the highest degree of health in the stock and freedom from loss before lambing ever recorded on this farm. The lambing-results were excellent. In former years there was generally a proportion of pining ewes in April, but in 1938 these were entirely absent. The improved nutritional status of the stock brought about by the phosphate of lime and salt, together with the stimulating effects of cobalt, made for a high level of well-being in the animals.

THE PREVENTION AND CURE OF PINE DISEASE BY COBALT.

THE TREATED GROUP ON OCTOBER 5th 1937.

Treatment - 1 mg. Cobalt per day for 14 days from Aug: 16th onward

NOTE the vigorous and healthy appearance.

THE CONTROL GROUP ON OCTOBER 5th 1937.

No treatment.

Note the depressed and pining state of these Hoggs.

THE CONTROL GROUP AFTER TREATMENT.

The photo. was taken on November 7th 1937.

3. Cobalt was given to two pining cows on a farm on the Andesite in 1937. On this farm some of the cows usually go off colour each autumn. They get dry and tight in the coat, dirty in the hair, and go back in condition. 5 mg. cobalt per day, in the form of cobalt chloride, was fed along with salt and some concentrates. Only one of the cows, however, would eat the mixture, and she made a quick recovery. The other cow showed no improvement. She was thereupon given 5 mg. cobalt per day without salt, when she gradually returned to normal.

4. A controlled test with cobalt was carried out in the early months of 1938, not on a pining farm but on a low-ground farm well known for its powers of turning pining sheep. The idea was to find if the form of incipient anaemia which is usually present in a proportion of pregnant ewes on practically all classes of farms would respond to cobalt. 90 Half-bred ewes which were the leanest and poorest of the flock at the end of winter were drawn out for the test. 45 of the ewes were given 2 mg. Co. per head per day, mixed with salt and some concentrates, for 31 days prior to lambing. The other 45 ewes were kept as controls in a separate enclosure. They received salt and concentrates only. The treated ewes made a quick response both in vigour and appearance. They were fresher and brighter and were much more active right up to the time of lambing. They also lambed sooner,

being more in accordance with schedule. Whether this was due to some few days difference in tupping it was impossible to tell. Owing to the exceptionally favourable weather during the lambing season of 1938, it was difficult to ascertain any difference in the young lambs themselves. The results of the experiment, however, were in line with the findings of a series of tests carried out by the writer on this aspect of the question on a large number of lowland flocks in previous seasons, the material used being crude oxide of iron and steamed bone flour, both singly and in combination. These tests have not been detailed in this thesis except for brief references on pages 137 and 138. All of these experiments agree in showing that the anaemia of pregnant ewes will respond to the same treatment as the anaemia of pine disease.

Altogether, in the experiments described in this section of the thesis, some 15 pining ewes, 55 pining hoggs, and 2 pining cows were treated with cobalt in 1937. All were restored to health except 2 ewes and 1 hogg which died. In addition, 560 sheep on a pining hill farm were treated for preventive purposes from January 1938 onwards. 90 Half-bred ewes were used in a controlled test on a non-pining low-ground farm in order to obtain information on an allied aspect of the problem.

Discussion.

Experiments are described in which cobalt

proved effective in controlling pine disease in sheep in the East Borders. This is the first occasion in which this substance has been used for the treatment of farm live-stock in this country. In a controlled test with hoggs, the administration of 14 milligrammes of cobalt per sheep entirely prevented the occurrence of the disease for six months on severe pining land. The consumption of cobalt reckoned over the whole period was less than 0.1 mg. cobalt per day. Pining sheep were repeatedly cured in several experiments by giving 14 doses of 1 mg. cobalt each, spread over a period of three weeks. The cure remained effective for many months. Attempts to deal with the disease with $\frac{1}{2}$ mg. doses were only successful where pining was in its early stages.

In previous tests, the administration of $\frac{1}{3}$ oz. per day of crude oxide of iron had proved markedly beneficial. Taking the cobalt content at 50 parts per million as ascertained by Dr. Tocher, this works out at 0.47 mg. cobalt per day. As treatment was generally given for 21 days, the cobalt consumption was approximately 9.8 mg. Though the digestibility of cobalt in this form is not known, the total quantity agrees more or less with the amounts used in the experiments now under discussion.

Regarding investigations elsewhere, Filmer and Underwood (84) found that 0.1 mg. cobalt per day was the minimum effective dose for curative purposes in

enzootic marasmus. This quantity was given daily for many months. The results in the East Borders show, however, that daily administration over a long period is not essential. Sheep can be given sufficient cobalt in a few days to effect a cure and to carry them on for a considerable period thereafter. Hopkirk (87) obtained successful results in New Zealand by dosing at the rate of 1 mg. cobalt per day, doses being given once or twice a week.

The influence of cobalt in animal nutrition has been studied by several workers. Waltner and Waltner, quoted by Underwood and Filmer (78), found that the addition of cobalt to the diet of rats produced a marked increase in the number of red blood cells. A similar result was noted in dogs by Mascherpa, quoted by the same authors. Other workers have confirmed these results. Beard and Myers, quoted by Cunningham (88), found that cobalt was a useful supplement in curing anaemia in rats produced by cow's milk. Cunningham, however, doubted whether a true anaemia was developed in rats fed on this diet.

Preliminary work in Australia and New Zealand on the use of cobalt for the treatment of nutritional anaemias in sheep has already been referred to (page 207). Cobalt was later demonstrated by Filmer and Underwood (85) to be present in many of the iron compounds commonly fed to live-stock. The writer also ascertained its presence in crude oxide of iron.

Evidence was obtained by Filmer and Underwood (86) that the presence of nickel tends to assist the action of cobalt when the quantity of the latter is relatively small. At a still later date, namely, January 1938, Hopkirk (89) reported that the incidence of bush sickness can be correlated with the cobalt content of pastures. He states that where sheep only are affected, the cobalt content varies from 0.01 to 0.04 parts per million; where cattle but not sheep are affected, the cobalt content usually lies between 0.04 and 0.07 parts per million. Healthy pastures usually contain 0.07 p. p. m. or over.

It will be apparent from the results of the investigation detailed in this thesis that cobalt is of prime importance in the prevention and cure of pine disease in the East Borders. In this respect the disease may be regarded as similar to bush sickness, enzootic marasmus, coast disease, and associated ailments. It would be a mistake to assume, however, that a deficiency of cobalt is the only cause of the malady in the East Borders. It has already been shown that sheep in the pining area respond to phosphorus, assuming that the phosphorus compound used contained no trace of nickel or other potent trace element. It seems certain that phosphorus and other structural elements are often lacking from the produce of pining soil. All the available field evidence which has been quoted at length in the earlier parts

of this thesis lends support to this view. J. Stewart (90) demonstrated the reduced powers of assimilation which occur in sheep suffering from a phosphorus deficiency. It seems likely, therefore, that in pine disease the sheep become debilitated in the first instance through predisposing causes in this province, and that under these circumstances cobalt is helpful in promoting the processes of assimilation and metabolism. The same seems to hold good in the type of anaemia in pregnant ewes already mentioned.

Little is precisely known as to the action of cobalt. Any views on the subject are merely conjecture. It may be that it is not essential to metabolism when the nutritional level in other respects is satisfactory. Otherwise, how is it that the administration of phosphorus which contained no trace of cobalt effected a cure in pining sheep?

Summary.

1. Pine disease in sheep in the Cheviot area has been cured and prevented by the administration of cobalt in the form of cobalt chloride.

2. The disease is not due to iron deficiency.

3. The administration of 1 mg. cobalt per day for 14 days was sufficient to prevent the disease on severe pining land for a period of six months. A similar quantity was effective as a cure.

4. The intra-muscular injection of cobalt for

curative purposes was not satisfactory. Recovery was slow.

5. The beneficial results obtained from the feeding of iron compounds are attributed to the presence of cobalt, and perhaps also other trace elements, in the iron compounds used.

6. On non-pining farms, either hill or lowland, pregnant ewes which are in somewhat poor condition will respond to iron compounds and to cobalt.

21. PRACTICAL CONSIDERATIONS.

At the conclusion of each stage of the experimental work, the results were carried into practice in the East Borders and other districts with the ready co-operation of a large number of farmers. Thousands of sheep were dealt with during the past three years. The possibilities, therefore, are well known. As referred to earlier, the feeding of minerals direct to sheep has many advantages over the treatment of the soil. The results are immediate, the cost is small, and it is the only feasible method in inaccessible country. Remarks therefore will mainly be confined to the feeding aspect. Brief references, however, may be made regarding the treatment of herbage.

Treatment of Herbage.

In the early stages of the investigation when the iron deficiency theory was under consideration, 2 acres of a pining field were treated with 1½ cwts. per acre of sulphate of iron, on September 3rd 1935. The cost was defrayed by the writer. The quantity was large, but it was thought desirable to produce a major effect. The dressing, however, tended to brown the grass, which remained poorer to the end of the season. Some pining hoggs were put on the field but they did not appear to do any better. In 1936, ewes and lambs did particularly well on this field, all mineral being

purposely withheld from them. The result was on the whole satisfactory.

In May 1936, a controlled test with ewes and lambs was conducted on another pining farm, 4½ acres of a field being treated with 1½ cwts. per acre of sulphate of iron on 12th May. 4½ acres of a control portion adjoining was fenced off. All the work of weighing, measuring, and sowing, etc., as indeed in all other tests reported in this thesis, was done by the writer personally.

The grass came away well owing to heavy rain, and on May 28th, 10 Cheviot ewes and 10 Cheviot lambs were put on each section. The weights of the lambs and other particulars during the test were as follows.

	Wt. May 28th lbs.	Wt. July 2nd lbs.	Increase lbs.	Death	Average rise in wool. (ewes) July 2nd
Treated Ground	18.5	29.4	10.9	1	0.4"
Control	19.8	31.8	12.0	-	1.0"

The results were unsatisfactory. The ewes on the treated ground never did well. They received a check and could scarcely be clipped on July 2nd. The lambs also did not thrive well. There was some scour among them and one of them died. The dressing of sulphate of iron was too large. It produced a flush of grass, and other effects, which upset the animals.

On September 7th 1936, nine pining hoggs were put on the iron enclosure. They started to die,

BOX FOR MINERAL FEEDING ON HILL FARMS.

This type of box was introduced by the writer in 1935.

however, and in the end all died. The effect of treatment on the grass could be seen for two years.

These experiments are mentioned to show the risk of putting hill sheep, or pining sheep, on fields which have been dressed with materials that produce a flush of grass.

The possibilities of dressing pastures with cobalt are referred to by Hopkirk (90). He reports that from ¼ to ½ lb. of cobalt chloride per acre has given good results. This might also be tried in the Borders. Reference has already been made on pages 86 and 87 to the question of dressing pining land with phosphatic manures. An extension of this practice under suitable conditions is called for. It is necessary to point out, however, that a difficulty in dressing hay with any of these materials is that hill sheep are often disinclined to eat hay in a mild winter, and it is after such a winter that pining is worst.

Points on Mineral Feeding.

It is a simple matter on any hirsel to place mineral boxes at suitable points on the hill land. The illustration shows the type of box which was introduced by the writer into the East Borders in 1935. These boxes are 2 feet 6 inches long by 15 inches high with a retaining board 6 inches high in front. The back is boarded up. Two heavy battens of wood about

3 feet long are nailed to the bottom. The cost is 4/6d. The capacity is 20 lbs. of mineral. The main feature is the small size of the box which enables it to be easily shifted should the ground get dirty. This is a disadvantage with the ordinary mineral brick fixed to a post. A certain amount of rain does no harm to the mineral. One box to 60 sheep is ample. Thus, assuming that the normal life is four years, the annual cost of boxes on a hirsel of 600 sheep is approximately 12/-.

A common complaint among farmers regarding proprietary mineral bricks is that a certain proportion of hill sheep tend to eat an excessive quantity, resulting in scour and other disorders. The same criticism, however, has not been made against the mineral mixture introduced by the writer. The reasons probably are that the mixture is simple; most of it is not readily soluble; it contains no substances of the drug category though cobalt now comes into this class; the proportion of salt is not unduly high.

There is no real difficulty in getting hill sheep on any farm to eat out of boxes, though they may take several weeks when first introduced on to the hirsel. The placing of rock salt in the vicinity soon attracts them. Thereafter the lambs learn from their mothers and no further difficulty arises in future years. At least 95 per cent of sheep can be depended on to partake. On some 20 hill farms where

the prescription of the writer has been closely followed, all farmers have been successful, without exception. Reports from other parts of the country sometimes indicate a difficulty in feeding minerals by this method. Orr and Fraser (92) tried it out in Argyllshire but had to make a change as the sheep would not eat the mixture. A quantity of feeding stuff had to be incorporated. The trouble, however, was probably an unsuitable type of mineral mixture. It contained 33.3 per cent of carbonate of lime. No oxide of iron was included. It is suggested that the feeding of carbonate of lime to pregnant ewes in a high proportion such as this is undesirable. It has been expressly avoided in the Border experiments, and though some farmers have tried it in their mixtures the reports have sometimes not been so favourable.

Crude oxide of iron will no doubt continue to be used in many places owing to its cobalt content. It has, however, certain disadvantages. It is extremely dirty to handle. It discolours the wool of sheep about the neck, and also under the fleece should the sheep rub themselves on the boxes. While it scours out of the fleece, buyers are sometimes inclined to offer less for such wool. Again, it is the recognised rule at the opening sale of hill lambs at Hawick that top Cheviot wether lambs must not be dipped or treated in any way prior to sale. Oxide of iron on the fleece seriously depreciates their value.

Consignments have dropped as much as 7/6d. per head owing to this cause. Oxide of iron, however, does not require to be used after lambing. Steamed bone flour is sufficient. To take another point, the suggestion has been made that the proportion of broken-mouthed ewes is increased with the use of oxide of iron. The fall in value in this case is approximately 10/- per head. On investigating these complaints, it has been found that other causes have probably been responsible. These difficulties are now happily removed as steamed bone flour and cobalt are the main constituents now advised. The mixture suggested for hill sheep, as a result of experiments, is

1 part sterilised steamed bone flour,

1 part salt,

A trace of cobalt chloride.+

+ Add cobalt chloride in accordance with the following scale, per sheep. 30 mg. Co. to ewes during pregnancy; 10 mg. Co. to ewes nursing; 10 mg. Co. to ewes before tupping. Hoggs, etc., can be given the same mixture.

Mineral feeding has been found of special value at three different periods, namely, (1) to ewes before tupping; (2) to ewes during pregnancy; (3) to lambs after weaning. On numerous low-ground farms, small lambs after weaning have been increased in value by 2/6d. per head by a course of mineral treatment on

the lines described, at a cost of less than 1 penny per head.

Annual Cost of Mineral Feeding with Cobalt.

From a number of field trials with hill sheep in which the amount of mineral consumed was recorded by the writer, (instances of which have already been referred to on page 215), the following estimate has been prepared. The estimate refers to a hirsel of 600 ewes, gimmers, and hoggs, together with the corresponding quota of lambs and tups. The mineral mixture is intended to be left out all the year; one box is allowed to 60 sheep.

	£	s.	d.
4 cwts. sterilised steamed bone flour @ 7/6	1	10	-
4 cwts. salt @ 3/6		14	-
144 grammes cobalt chloride		4	-
Mineral boxes; annual charge		12	-
Total ...	£3	-	-

The cost per annum amounts to £3 for a whole hirsel of 600 sheep, or 1.2 pence per sheep. The actual cost in several cases was less than this. The figure of 1 penny per sheep may be taken as a fair estimate.

Practical Advantages.

The chief advantages of mineral feeding to

sheep, on the lines worked out, have been found as follows.

Pine disease is abolished.

The changing of the flock as a preventive of the disease in endemic areas is rendered unnecessary.

There is a reduction in the number of tup-eild ewes. There is an appreciable increase in the number of twin lambs.

The appetite and general condition of the pregnant ewe is improved. There is therefore usually less abortion.

The ewe keeps more active and vigorous when she begins to get heavy in lamb. There is less pregnancy toxaemia in lowland flocks among ewes carrying twins.

Ewes tend to lamb more up to time.

Nursing lambs make better progress. Small lambs after weaning in hill or lowland flocks, where minerals have not regularly been fed, are markedly increased in value.

22. CONCLUSIONS.

The following conclusions are drawn from the main work of the investigation.

1. Pine disease in the Cheviot region is a nutritional anaemia caused by mineral deficiency in the soil or herbage of affected areas resulting in defective iron metabolism.

2. The disease occurs in an endemic form on the Andesite formation in the East Borders. Both hill land and arable land are involved. The affected district covers an area of approximately 80 square miles and carries 40,000 head of sheep.

3. There is evidence that the disease first attained serious proportions in the Cheviot region about the beginning of the nineteenth century. This was due to far-reaching changes in the system of sheep husbandry, and in sheep-breeding in particular. It is probable that the local races of sheep were formerly resistant to the malady. This view is supported by the fact that native sheep are maintained on pining land in Scotland at the present day without a change of pasture. The problem therefore has a genetic aspect which appears to offer scope for enquiry.

4. The disease is not due to iron deficiency.

5. The administration of minute quantities of cobalt prevents the occurrence of the disease on

pining land and also acts as a cure. The beneficial results obtained from the feeding of iron compounds are attributable to traces of cobalt in the materials used.

6. Small quantities of phosphorus, free from cobalt, are of curative and preventive value. The feeding of phosphorus compounds only, gives successful results in practice. A deficiency in this element is regarded as a predisposing cause of the malady.

Both phosphorus and cobalt are presumably lacking in sufficient quantity from the produce of pining soil. The precise significance of cobalt in animal nutrition, apart from its potency in assisting the utilisation of iron, is unknown.

7. Experimental evidence shows that no effect is produced by the administration of traces of copper to pining sheep.

8. The condition is primarily one of mineral deficiency. The influence of parasitic infestation of the digestive tract is entirely secondary. The treatment of pining sheep for mineral deficiency alone, with materials that possess no known anthelminthic properties, is successful in well over 95 per cent of cases. This applies equally to animals which are mildly affected, and those which are in an advanced stage of the malady.

9. The disease has a close similarity with bush sickness in New Zealand, enzootic marasmus in Western

Australia, coast disease in South Australia, and certain pining diseases in other countries. It appears to be different in origin from salt sickness in Florida and lecksucht in Holland.

10. In the Border Counties, the nutritional anaemia represented by pine disease is not confined to the Andesite formation. It is manifested in various forms under diverse conditions of soil and of sheep-husbandry. These various types are as follows :-
(1) An endemic form of the disease is found on the Andesite and also in localised areas on many other geological formations in the Border Area. This form occurs both in hill and in arable districts. (2) A sporadic type is liable to occur in a proportion of the flock on any hill farm, following a severe winter during which the stock have become debilitated.
(3) A type of anaemia associated with pregnancy, and also prevalent among small lambs after weaning, is found in flocks in all districts, both hill and arable, and on all types of soil.

All of these types respond to the same treatment as pine disease on the Andesite.

11. It is probable that the low content of available phosphorus in many soils in the area has some connection with the occurrence of these anaemias.

12. It is suggested that these various forms of anaemia may be widely distributed in other parts of Scotland.

13. The system of mineral feeding worked out during the course of this investigation has been used upon thousands of sheep with markedly beneficial results. Apart from its effect upon pine disease, or anaemia, it has other advantages. There is a decrease in the proportion of tup-eild ewes, and an appreciable increase in the number of twin lambs. There is a reduction in the rate of abortion, and, in lowland flocks, the incidence of pregnancy toxaemia is lessened. Deaths among ewes are reduced. Lambs make better progress while nursing.

14. In practice, pine disease and allied conditions can be prevented, and some of the above advantages secured, by an annual outlay of one penny per sheep.

A P P E N D I X (1).

SHEEP STOCKS ON EAST BORDER HILL FARMS, 1935.

Farm No.	Acreage of Hill Land.	No. of Ewes, Gimmers, & Hoggs.	Breed	No. of Crops	Lamb Crop at cutting %	No. of Ewes, Gimmers, & Hoggs, per acre.
1	1,030	701	Bf.	5	90	.680
2	450	400	Ch.	5	90	.888
3	1,026	1,020	Ch.	4	94.7	1.005
4	1,287	1,200	Ch.	4	85	.932
5	2,234	1,446 294	Ch. Bf.	3 5	93.5	.778
6	1,975	900 500	Ch. Bf.	5 5	94.2	.708
7	1,495	760 480	Ch. Bf.	4 4	93.6	.829
8	460	300	Ch.	4	100	.652
9	1,266	390 640	Ch. Bf.	5 5	85	.813
10	370	440	Bf.	4	90	1.189
11	850	690	Ch.	4	70	.811
12	700	560	Ch.	4	104.5	.80
13	580	675	Ch.	4	117	1.16
14	536	563	Ch.	4	95.4	1.050
15	3,380	3,400	Ch.	3	96	1.005
16	130	96	H.B.	3	125	.738
17	766	480 140	Ch. Bf.	4 4	90	.815
18	492	500	Ch.	4	90	1.016
19	840	560	Ch.	4	90	.666
20	200	200	Bf.	cast ewes	100	1.0
21	3,641	1,740 340	Ch. Bf.	3 4	86	.571
22	750	720	Ch.	3	100	.960
23	610	400 260	Bf. H.B.	4 3	100	.942
24	1,000	1,240	Bf.	5	115	1.24
25	735	589	Ch.	4	100	.801
26	671	280 280	Ch. Bf.	5 5	100	.834
Total :	ACRES 27,474	23,184			Av. 92.38	Av..843

OCCURRENCE OF SHEEP BREEDS.

	%
Cheviot	74.2
Blackface	24.3
Half-bred	1.5
	100.0

A P P E N D I X (2).

NO. OF CATTLE SUMMERED ON EAST BORDER HILL FARMS, 1935.

Farm No.	Acreage of Hill Land.	No. of Cows.	No. of Calves.	No. of Yearlings & 2yr-olds.
3	1,020	2	1	20
4	1,287	20	20	20
5	2,234	2	1	-
6	1,975	2	1	-
7	1,495	1	1	-
8	460	5	5	10
12	700	1	-	7
13	580	12	12	10
14	536	14	12	4
17	766	40	40	-
18	492	5	4	-
19	840	-	-	40
21	3,641	10	10	12
22	750	-	-	-
23	610	10	10	36
24	1,000	-	-	-
25	735	12	12	4
26	670	4	4	6
27	720	8	8	20
28	232	3	2	16
29	200	-	-	30
30	7,200	15	15	28
Total ...	28,143	166	158	263

A P P E N D I X (3).

EXPERIMENT WITH MINERALS AND VITAMINS, 1935.

Weights of Hoggs.

Group I Treated				Group II Controls			
Hogg No.	Jan. 4th lbs.	Feb. 21st lbs.	May 18th lbs.	Hogg No.	Jan. 4th lbs.	Feb. 21st lbs.	May 18th lbs.
21	68	61	80	1	68	62	80
22	63	62	81	2	63	62	79
23	64	65	80	3	70	62	90
24	56	58	70	4	53	55	75
25	58	68	86	5	54	44	56
26	52	55	77	6	60	57	86
27	64	65	86	7	62	58	77
28	53	56	74	8	59	62	82
29	50	54	72	9	59	58	72
30	61	61	80	10	56	59	72
31	61	67	88	11	57	58	80
32	61	58	70	12	55	56	77
33	63	62	84	13	61	67	82
34	62	65	89	14	51	51	68
35	58	54	60	15	60	58	76
36	61	64	66	16	60	56	-
37	71	68	90	17	-	(65)	(86)
38	64	63	86	18	50	42	77
39	64	66	89	19	60	57	77
40	62	63	81	20	52	50	67
Average	60.08	61.75	79.45		58.42	56.53	76.27

A P P E N D I X (4).

EXPERIMENT WITH 60 HOGGS ON IRON AND AMMONIUM CITRATE, 1935.

Weights of Hoggs.

Group I. Treated Group.					Group II. Controls.				
Hogg No.	Sept 12th lbs.	Oct. 26th lbs.	Nov. 21st lbs.	Dec. 7th lbs.	Hogg No.	Sept 12th lbs.	Oct. 26th lbs.	Nov. 21st lbs.	Dec. 7th lbs.
891	49½	57	55	55	921	37	32½	39	41
892	57	67	69	68	922	55	67	66	68
893	59	-	-	-	923	52	48½	48	48½
894	50	63	63½	63½	924	48	55½	56	56½
895	46	58	59½	59	925	47	57	57½	57
896	44	54½	55	56½	926	50	58	57	59
897	56	65	66½	66	927	50	58	58	57
898	45	54	54	56	928	47	52½	54½	55
899	55½	64	64	62	929	51	64½	63½	66
900	52	65	66	67	930	51	58	57	59
901	55	65	66	68	931	56	62	62	61½
902	51	62	63	65	932	43½	52	51½	50
903	48	59	58	59	933	59	64½	66	65
904	45½	56½	57	59	934	46	52	51	49½
905	51	59	57	58	935	45	55	57	59
906	49	61	61	61	936	49½	59	59½	60
907	39	40	35½	36	937	49	59	59	59½
908	53	61	61	62½	938	41	49	49	50½
909	64	72	71	72	939	52	57	57½	56½
910	46	57	55½	56	940	48	48	43½	42
911	44	-	-	-	941	45	51	52½	52
912	49½	57	55	57	942	45½	44	41½	38½
913	54	59	60½	60	943	49	59½	61	61½
914	52	63½	61	64	944	53	63	63	64
915	47	62	64½	66	945	50½	59	57	57½
916	38	46	45	46	946	44½	55½	57	56½
917	43½	52	53	55	947	43	45	42½	42
918	45	53	52	53	948	49½	56½	54	55
919	50	56½	57	58	949	45	52	54	55
920	43	55	53	56	950	46	58	59½	62
Average	48.7	58.7	58.5	59.4	Average:	48.2	55.0	55.1	55.4

A P P E N D I X (5).

EXPERIMENT WITH 60 HOGGS, 1935.

Table showing Haemoglobin values, Conjunctiva readings, and Temperatures.

Group I. Treated Group.				Group II. Controls.			
Hogg No.	Haemoglobin % Dec. 9th	Conjunctiva Dec. 7th	Temperature °F Dec. 7th	Hogg No.	Haemoglobin % Dec. 9th	Conjunctiva Dec. 7th	Temperature °F Dec. 7th
891	10.0	30	104.1	921-	8.4	20	104.9
892	11.0	36	104.0	922	-	26	105.2
893	-	-	-	923-	9.4+	20	104.2
894	10.3	36	105.2	924-	10.5	34	106.8
895	10.5+	28	104.4	925-	10.6	36	106.4
896	10.0	36	104.3	926-	9.6	34	104.4
897	10.0+	30	104.6	927-	10.5	36	104.7
898	9.2	34	103.5	928-	7.2	18	104.0
899	10.3+	34	103.5	929	-	36	105.2
900	10.4	25	103.1	930-	8.6	20	104.0
901	10.3	28	104.2	931-	9.2	18	104.8
902	10.0	34	102.8	932-	10.0	36	104.4
903	10.4	36	104.8	933	10.5	20	105.6
904	11.0+	34	104.0	934-	8.6	30	104.8
905	11.0	36	104.8	935-	8.8	36	105.1
906	9.8	36	104.0	936-	-	36	105.3
907	7.7	20	105.2	937	-	42	104.8
908	9.6	20	105.5	938-	8.1+	34	103.6
909	11.4+	36	104.4	939-	-	30	104.3
910	-	25	105.1	940-	7.5+	20	105.0
911	-	-	-	941-	8.7	36	104.8
912	11.9	44	104.5	942-	8.6+	30	104.0
913	10.0	36	103.7	943-	10.3	30	105.2
914	11.6	26	105.4	944-	10.0	30	105.0
915	10.1	30	103.8	945-	10.0	20	104.6
916	10.3	30	104.2	946-	11.5	34	105.0
917	9.1	34	104.0	947-	8.1+	30	105.0
918	11.3	36	103.1	948-	11.4	30	105.2
919	9.3	20	104.2	949-	10.0	30	104.8
920	10.3	20	105.2	950-	9.3	20	104.2
Average	10.4	31.2	104.27	AVERAGE :	9.4	29.4	104.84

\+ Blood tested November 5th.
\- Pining Hoggs.

A P P E N D I X (6).

EXPERIMENT WITH HOGGS ON COPPER, 1935.

Copper Group. Treated Dec.11th-31st,1935.					Iron Group. Treated Dec.11th-31st,1935.				
Hogg No.	Wt. Dec. 7th lbs.	Conjunctiva. Dec. 7th	Wt. Jan. 15th lbs.	Conjunctiva. Jan. 15th	Hogg No.	Wt. Dec. 7th lbs.	Conjunctiva. Dec. 7th	Wt. Jan. 15th lbs.	Conjunctiva. Jan. 15th
924	56½	34	51½	26	926	59	34	54½	34
925	57	36	47	20	930	59	20	57½	36
927	57	36	52	30	939	56½	30	51	30
931	61½	18	55	19	941	52	36	47	34
932	50	36	45	30	943	61½	30	55	34
934	49½	30	37	17	944	64	30	57	28
935	59	36	54	34	946	56½	34	53	36
936	60	36	53	20	947	42	30	43	34
938	50½	34	46	25	948	55	30	50½	32
945	57½	20	54½	30					
949	55	36	49	36					
Average	5577	32	4945	26	AVERAGE	5616	304	5205	331

A P P E N D I X (7).

EXPERIMENT ON HOGGS WITH DI-SODIUM PHOSPHATE, 1936.

Group I Treated Group+			Group II Controls+			Controls Treated.				
	Average			Average			Average		Average	
Wt. Aug. 7th	Wt. Sept 28th	Conjunctiva Sept 28th	Wt. Aug. 7th	Wt. Sept 28th	Conjunctiva Sept 28th	Hogg No.	Wt. Oct. 1st	Conjunctiva Oct. 1st	Wt. Oct. 21st	Conjunctiva Oct. 21st
lbs.	lbs.		lbs.	lbs.			lbs.		lbs.	
36½	31	21	38½	38	21	17	39½	25	38	30
30	32	31	35	38½	32	18	38	35	41½	39
37	39½	40	36	35	37	19	40	25	40	32
35	44	40	38	39	35	20	42½	20	46	28
36	46	40	38	34	30	21	37½	30	38	30
35	41½	29	32	39	36½	22	37	31	41	34
35	40	36½	37	35	40	23	36	17½	36	26½
38	38	42½	38½	39½	20	24	39	23½	39½	25
31	40	39	37	37	32	25	35½	31	40	37½
38½	39½	35	39	35	35	26	37	31	36	32
29	36	30	39½	41	38	27	34½	34	37	38
33½	38	42	34	36½	35	28	37	26	38½	35
39	42½	33	41½	48	38	29	40½	32½	44½	30
34½	47½	38	39	41	37½	30	46	33½	50½	39
31½	41	31	34	42½	25	31	43	36½	49	37½
37	46	40	31	42½	36½	32	41½	39	47½	36½
37	43	40	34	46	40	33	40	39	46	39
38	-	-	33½	44½	31	34	45	43½	49	35
36	-	-	33½	42	31	35	48½	38	50	38
32½	-	-	35½	-	-					
35	40.3	35.7	36.2	39.6	33.1		39.8	31.1	42.5	33.7

+ Hoggs not individually numbered.

A P P E N D I X (8).

EXPERIMENT ON HOGGS WITH COBALT CHLORIDE, 1937.

Group I					Group II				
Hogg No.	Wt. Aug. 16th lbs.	Average Conjunctiva Aug. 16th	Wt. Oct. 5th lbs.	Average Conjunctiva Oct. 5th	Hogg No.	Wt. Aug. 16th lbs.	Average Conjunctiva Aug. 16th	Wt. Oct. 5th lbs.	Average Conjunctiva Oct. 5th
61	37½	20	48	36	71	35½	35	33	25
62	39	30	46	38	72	34½	40	44	38
63	33½	35	41½	35	73	34½	35½	42½	40
64	39	33	46	35	74	41½	38	41½	32½
65	32½	35	37½	34	75	35½	40	42	38
66	42	30	50	35	76	30	33	25	25
67	42½	40	50½	40	77	34½	34	37	31
68	38½	40	48	38	78	39	36	42	36
69	39	38	51	40	79	42	40	41	35
70	40	40	44	38	80	37	39	42	36½
Average	3835	34.1	4625	36.9		36.4	37.0	39.0	33.7

Controls Treated.

(Treated October 5th onwards)

Hogg No.	Wt. Oct. 5th lbs.	Average Conjunctiva Oct. 5th	Wt. Dec. 9th lbs.	Average Conjunctiva Dec. 9th	Stops in wool
71	33	25	38	36½	stop
72	44	38	44	38	none
73	42½	40	45½	43	stop
74	41½	32½	48	35½	stop
75	42	38	47	40	none
76	25	25	27	36	stop
77	37	31	-	-	-
78	42	36	43	43½	stop
79	41	35	44½	37	stop
80	42	36½	46½	40	stop
Average	39.0	33.7	42.6	38.8	

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