SOME FURTHER STUDIES ON THE ETIOLOGY OF
HAEMATURIA VESICALIS (RED WATER)
IN CATTLE

by

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CONTENTS

Introduction.................................................. 1

Definition.................................................... 1

Historical..................................................... 1

Geographical Distribution..................................... 1
  Europe....................................................... 1
  America..................................................... 2
  Australasia............................................... 2
  Africa..................................................... 2
  Asia....................................................... 2

Conditions of Occurrence.................................... 2
  General.................................................... 2
  Local Conditions.......................................... 3
    Altitude................................................ 3
    Climatic Conditions.................................... 3
    Table I - Temperature.................................. 4
    Table II - Precipitation................................ 5
    Table III - Total Precipitation........................ 6
    Table IV - Sunshine..................................... 7
    Graph I - Temperature, Precipitation and Sunshine.... 8
    Geographical Location.................................... 9
    Geological Conditions.................................... 9
    Soil Types................................................ 9
    Browse (Native and Cultivated)........................... 10
    Biotic Conditions........................................ 10
    Water Supply.............................................. 10

Discussion of Local and General Conditions............... 11
  Species of Plants.......................................... 11
  Stage of Growth of Plants................................ 11
  Climatic Conditions....................................... 11
  Nature of Soil............................................ 11

Recorded Theories of Causation.............................. 12
  Bacteria and Fungi........................................ 12
  Protozoan Parasites....................................... 12
  Metazoan Parasites........................................ 12
  Pentastomes................................................ 12
  Nutritional and Metabolic Origin.......................... 13
  Mineral and Plant Poisoning................................ 13
Contents (Contd).

Experimental Reproduction

By Infection

By Ingestion

- Bracken and Bracken Spore Feeding
- Oxalic Acid and Oxalates
- Sorrel Feeding
- Plant Extracts

Local Surveys

- Plants
- Soil, Water, etc.
- Economic

Treatments

Characteristic Symptoms and Factors

- Lesions in the Bladder
- Blood in Urine
- Reaction of Urine
- Blood Conditions
- Age of Animals Affected
  - Table V - Age When Affected

Experimental Data

- Survey of Affected Area
- Source of Materials
- Methods of Analysis
- Analysis of Materials
  - Soils
    - Table VI - Reference Description of Soils
    - Table VII - Silica and Organic Content of Soils
    - Table VIII - Ratio of Magnesium and Phosphorus to Calcium in Soils
    - Table IX - Ratios between Calcium and Iron and Aluminium in Soils
- Feeding Stuffs
- Table X - Reference Descriptions of Mixed Hays
- Table XI - Mixed Hays - Ash, Silica, Iron and Aluminium
- Table XII - Oat Hay - Ash, Silica, Iron and Aluminium
- Table XIII - Mixed Hays - Calcium, Magnesium, Phosphates, Sulphates and Manganese
- Table XIV - Oat Hays - Calcium, Magnesium, Phosphates, Sulphates and Manganese
Contents (Cont'd).

Waters. ................................................................. 36
  Table XV - Reference Description of Waters........ 36
  Table XVI - Mineral Content of Waters............. 36

Urines. .............................................................. 37
  Table XVII - Urines - S.G., Silica and pH....... 37

Bladder .............................................................. 38
  Table XVIII - Mineral Content of Bladder....... 38

Coral Rock Flour .................................................. 39
  Table XIX - Coral Rock Flour - Analysis........ 39
  Table XX - Coral Rock Flour and Coral Compar­
  ative Composition................................. 39

General Discussion of Results................................. 40

Practical Considerations and Recommendations.......... 40

Summary ..................................................................... 41

Conclusions ............................................................. 41

Acknowledgements .................................................... 42

Bibliography ............................................................ 43

Appendix .................................................................... 56
SOME FURTHER STUDIES ON THE ETIOLOGY OF
HAEMATURIA VESICALIS (RED WATER)
IN CATTLE.

INTRODUCTION

Haematuria Vesicalis (70) (71), (Red Water (93)) is also variously known as Stallrot der Rinder (70), Hematurie chronique des bovides (70), Chronic Haematuria (31)(32)(66) (83), Enzootic Haematuria (38) (66), Chronic Haemorrhagic Cystitis (17) (66), Vesical Haematuria (66), Bovine Haematuria (57); these are all descriptive names for a specific disease which occurs in adult cattle and is distinctively characterized by the presence of red blood corpuscles in the urine. This blood apparently originates from lesions formed in the mucous membrane of the bladder. It would appear, in uncomplicated cases, that the primary pathological conditions are almost entirely confined to this organ (16) (33) (51) (76), and that the frequent passing of bloody urine, which may occur at intermittent or for prolonged periods, is a secondary condition. This loss of blood leads to anaemia and a progressive course of emaciation which finally results in the death of the affected animal.

The disease occurs in many countries, but is confined to fairly well defined local areas, under similar agricultural conditions.

Many theories have been advanced as to its cause and several curative treatments suggested, but none, so far, entirely satisfactory.

The consensus of opinion of recent investigators McKee and McKee (93), Grauer (51), Bruce (14), Craig (33), Dickinson and Bull (38), favours the proposition that the causation of the disease is probably due to faulty nutritional conditions; therefore, it is to this phase of the problem that the present investigation has been directed, principally by the application of chemistry to a serious problem in animal husbandry.
SOME FURTHER STUDIES ON THE ETIOLOGY OF
HAEMATURIA VESICALIS (RED WATER)
IN CATTLE.

DEFINITION.

The disease may generally be described as one affecting mature cattle, especially dairy cows, and is characterized by the passage of unaltered red blood cells in the urine.

The colloquial name of "Red Water" has been given to this disease, as well as several others, on account of the presence of blood in the urine.

The symptoms, course, and anatomical changes have already been clearly and completely defined by others (Hoare (66)), (Hutyra and Marek (70)), (Hadwen (54) (57), (Kalkus (76)), et al.

HISTORICAL.

In Europe the disease has been recognized for nearly a century, and referred to by Anderson (1842) (6), Hubner, (1842) (69), Vaes (1843) (122), Vigney (1845) (14); it has been known for fifty years or more in Australia, and definite attention was drawn to it by T.H. Williams (125) in 1894. It has been investigated and recorded within the last quarter of a century in New South Wales by J.B. Cleland (24) (25), in 1911; in Ireland by Craig and Kehoe (1917) (32); also in England, Wales and Scotland (33); in New Zealand by J. Kerrigan (1925) (83); in Canada in 1907 by Bowhill (112); by Kalkus (1913) (76); in Washington, U.S.A.; by Case (20) in Hawaii (1911); by Kearney (82) in Africa (1912).

The disease has caused a considerable number of fatalities in cattle, and is still a source of loss in many regions; so that although the disease is historically old it presents a perennial economic problem to the farmer in the affected areas, because history, to date, has neither recorded the cause nor an effective permanent remedy.

GEOGRAPHICAL DISTRIBUTION.

Europe. The disease has been reported to occur in Baden (Hink (65)) Anacker), the Black Forest in Germany (71), in the Elbe region of France (56) (71); in Belgium (Lieniaux (87)); in Italy (Moussu (99)); in Austria (71);
Geographical Distribution (Cont'd)

Europe.

In Bulgaria (71); in the Suck Valley district in County Roscommon in Ireland (Craig and Kehoe (31); in Carnarvonshire and Merionethshire in Wales (Roberts)(109); in Cornwall in England and the North of Scotland (Craig)(33).

The disease occurs in certain districts of the Russian Carpathians. (Klobouk) (84).

America. References to the disease confine it to the State of Washington (Kalkus)(76) and Oregon (Simms)(116) in the United States of America; to the Hawaiian Islands (in the south island) (Case)(20); to the Fraser Valley district and portions of the Islands in British Columbia in Canada (Hadwen, Bruce (14)), and possibly Fraserburg and Latchford Bridge, Ontario, Canada, (Bruce)(14), (Grauer)(51); Antioquia (Columbia) (Scharrer)(113).

Australasia. The disease is known in the Mount Gambier and Mount Schank districts of South Australia (Dickinson and Bull)(38); in the Illawarra district of New South Wales (Cleland)(24); in Murchison and Inangahua districts, in the South Island, West Coast district of New Zealand, (Kerrigan)(83).

Africa. A reference has been made to its occurrence in Africa in mature cattle in the Lake Kivu district in Belgian Congo (Van Saceghem)(123), and in the Limuru district, Kenya, British East Africa (Kearney)(82).

Asia. In Formosa it is reported as affecting native cattle (Miyamoto)(98). Cases of the disease were detected in hill bulls used for experimental work at Muktesar (India) (Malkani)(72).

Therefore, the geographical distribution of this disease is wide enough to embrace practically all the countries of the world which utilize the bovine species for agricultural purposes.

CONDITIONS OF OCCURRENCE

General.

The disease is described as occurring in Germany with stall-confined cattle, during or after a dry summer, and when grazed on high-lying wooded pastures (71). In Bulgaria it is a disease of the high-lying land, from 2,500 to 7,000 feet above sea level. In France haematuria
Conditions of Occurrence (Cont'd)

General.

occurs in low-lying districts (71), and in hilly country with patchy land (56). In Ireland "it would appear to be associated with farms where much land is badly cultivated or has gone out of cultivation" (Craig and Kehoe)(31)(32). In Australia "it has been found that 'red water' occurs chiefly on those farms situated about the old volcanoes, Mount Gambier and Mount Schank" but may be "found on some farms outside the influence of the old volcanoes" (Dickinson and Bull)(38); in New Zealand on land once covered with beech species of trees, which "when tilled the land runs very rapidly into bracken fern." "In general the land has not been improved by the addition of artificial manures." (Kerrigan)(83); in British Columbia it appears on land "newly cleared" "or in partially cleared lands" in which the "fields were very sour" (Hadwen)(56). "It is essentially a disease of bench land upon which the bracken fern is a prominent plant" (Grauer)(51).

It seems generally established that the habitat of this disease is on high bench lands, growing bush or trees, which has recently been brought under cultivation for pasture and other purposes, with possible adjacent bush lands. The soil, unless thoroughly fertilized and cultivated after being broken, is usually sour or acid in nature.

Local Conditions.

The local conditions of the affected farms, in the Fraser Valley area, conform to those found in other parts of the world where the disease is, or was, prevalent.

Altitude. The altitude at which red water farms occur appears to be from 40 feet to 350 feet above sea level.

Climatic Conditions. The climatic conditions in the affected area are reflected in the following records of temperature, precipitation, and sunshine, based upon report for 1930 on Climate of British Columbia (37).
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<td>93</td>
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<td>48</td>
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TABLE II.

PRECIPITATION (INCHES)

TOTAL MONTHLY FOR 1930 AND AVERAGE

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<td>1.82</td>
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Total annual precipitation (inches)
### TABLE IV.

**BRIGHT SUNSHINE (HOURS)**

**TOTAL MONTHLY FOR 1930 AND AVERAGE**

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<td>62</td>
<td>98</td>
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<td>101</td>
<td>75</td>
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<tr>
<td>Average 23 yrs.</td>
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<td>76</td>
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<td>126</td>
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<tr>
<td>Average 18 yrs.</td>
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<td>81</td>
<td>132</td>
<td>170</td>
<td>233</td>
<td>229</td>
<td>295</td>
<td>263</td>
<td>181</td>
<td>109</td>
<td>57</td>
<td>39</td>
<td>1837</td>
</tr>
<tr>
<td>Average 2 Stations</td>
<td>47.5</td>
<td>78.5</td>
<td>119.5</td>
<td>148</td>
<td>198.5</td>
<td>194</td>
<td>256</td>
<td>227.5</td>
<td>159</td>
<td>101.5</td>
<td>55.5</td>
<td>42</td>
<td>1627.5</td>
</tr>
</tbody>
</table>
FRASER RIVER VALLEY AREA
CLIMATIC CONDITIONS
(Based upon average monthly figures as shown in Tables I, II, and IV)
Local Conditions (Cont'd).

It may be deduced from the above data that the climate of the affected area has a mild winter and a cool summer with a moderate annual precipitation. Showing a yearly average precipitation of 53.81 inches, with 1627.5 hours of bright sunshine per year, and a mean monthly temperature of 49°F, within a range of 94°F. and 5°F. The temperatures above the average occur within the period between April and October; the highest hours of sunshine, above the average, are experienced between the middle of March and the middle of September; the largest measure, above the average, of precipitation falls between the middle of September and the beginning of March.

Geographical Location. The disease occurs principally in the area known as the Fraser Valley district, consisting of the uplands bordering on the north and south sides of the Fraser River, encompassed on the west by Vancouver and by Hatzic on the east in respect to the north side of the river and on the south side as far east as Rosedale and south to the United States boundary, but not including the delta lands. It is recorded as occurring in the following municipalities: Surrey, Langley, Matsqui, Chilliwack, Maple Ridge and the Lillooet district, which are all in the above mentioned area and within a distance of approximately seventy miles inland from the Pacific coast of British Columbia. The disease has also been reported as occurring on Bowen, Galiano, Salt Springs and Vancouver Islands, which are all adjacent to the mainland of British Columbia.

Geological Conditions. The affected sections of the Fraser Valley are described geologically as composed principally of glacial drift, overlain in places by small thicknesses of marine deposits, which were laid down during glacial retreats of the Pleistocene time. "The glacial drift soils occur on the uplands which were formerly, and are still, in large part, heavily timbered. They are mostly sandy or sandy loam soils. The upland areas are being gradually brought under cultivation in places where the valuable part of the forest has been removed in lumber operations." (Johnson (74)).

The topography of the land is usually of a rolling nature with occasional fairly level areas.

Soil Types. The type of soil may be classed, generally, as coarse, sandy loam varying from a light brown to a dark chocolate colour. It is usually acid in reaction. The texture is often open and
Local Conditions (Cont'd).

readily leached and drained naturally.

**Browse (Native and Cultivated).** The native tree and herbage growth consists principally of alder (Alnus glutinosa, Med.), second growth fir (Abies balsamea, L. Mill.), birch (Betula occidentalis, Hook), vine maple (Acer circinatum, Pursh.), cedar (Thuja occidentalis, L.), bracken (Pteris aquilina), willow (Salix species), hazel (Corylus americana, Walt.), broadleaf maple (Acer glabrum, T. & G.), hemlock (Tsuga canadensis, (L.) Car.), cottonwood (Populus deltoides, Marsh.)

The prevailing pasture herbage consists of timothy (Phleum pratense), June grass or Canada bluegrass (Poa compressa), white clover (Trifolium repense), red clover (Trifolium hybridum), Orchard grass (Dactylis glomerata), perennial rye grass (Lolium perenne), red top (Agrostis alba), meadow fescue (Festuca elatior), Yorkshire fog or Velvet Grass (Holcus lanatus).

**Biotic Conditions.** The plant communities dominant in the affected areas are fire or burn indicators as would be expected to occur from logged and burnt off lands, whereas the plant indicators among the pasture plants are those usually associated with over-grazing (Clements (26)). It is also to be noted that the majority of herbage plants are acid-loving individuals.

**Water Supply.** The water supply on the majority of red water farms, in the Fraser Valley, is obtained from seepage wells varying from 12 feet to about 30 feet in depth, with some small creeks, surface water supplies, and a few deep artesian wells (Grauer (51), Mackenzie (94)).

**Discussion of Local and General Conditions.**

Generally the factors affecting the mineral content of hays and pastures have been classified by Orr (101)(102), Richardson et al (108), under the following headings.

The factors upon which differences depend are:

1. Species of Plants.
2. Stage of Growth of Plants.
3. Climatic Conditions.
Discussion of Local and General Conditions (Cont'd).

(1) Species of Plants.

It has been definitely established that there is an inherent difference in the mineral or inorganic compositions of different species of plants. The legume plants usually contain a large excess of calcium over phosphorus, whereas there is generally an excess of phosphorus over calcium found in the gramineous plants.

(2) Stage of Growth of Plants.

It is a well known fact that certain progressive changes in composition of plants are incident to advancement in maturity. Although ripening may alter the relationships of the digestible nutrients it has been found that the percentage of ash remains about the same, although they may be variable. Plants consumed as hay may be lower in their ash content than those consumed as pasture (Hopper and Nesbitt (68)).

(3) Climatic Conditions.

With variable seasonal climatic conditions there is a change in the amount of salts in the soil solutions, which is reflected by a variation in the composition of a given species of plant, from season to season.

These variations depend principally upon:

(a) The amount of sunshine.
(b) The temperature.
(c) The rainfall.

The amount of sunshine during the growing season of the plant has a marked influence on the ash content of hays and pastures. During periods of drought the amount of mineral substances in plants decreases, especially the calcium and phosphorus salts will be low. The ash content of plants varies with the soil moisture. The amount of rainfall is the most important of all factors that influence the chemical composition of grass (Archibald (8)), Holtz (67)).

(4) Nature of Soil.

Work done by Lawes and Gilbert (1856-1900) (86) showed that "the mineral composition of the mixed herbage is very directly dependent on the supplies available within the soil. Indeed the composition of the supply available within the range of the roots."
Discussion of Local and General Conditions (Cont'd).

Orr (101) concludes that "the chemical composition of pasture and the value of that composition to the needs of the grazing animal, give a new method of estimating the nutritive value of the pastures; correlations of certain definite nutritional disorders with definite deficiencies; correlations of the excellence of pasture with the proper balance of the nutrients whose amounts can be accurately determined by a chemical analysis." And it is "now recognized that animals are more likely to suffer from lack of inorganic salts, or of organic substances of unknown composition which are required in comparatively small amounts, than from an insufficiency of protein and fat-forming substances and that the deficiencies of mineral elements limit the rate of growth and production, and also they affect the health of the cattle."

A summation of the local conditions and factors, as they would affect directly the quality and chemical composition of the feeding stuffs and indirectly the nutritional problems of this area, presents strong evidence in support of the considered opinion of several workers (McKee and McKee (93), Craig (33), Dickinson and Bull (38) et al) that Red Water is a deficiency disease.

RECORDED THEORIES OF CAUSATION.

Previous investigations have advanced many theories in explanation of the causation or etiology of this disease, but so far none of them have been fully substantiated.

It has been suggested that the disease may be due to:

(1) Bacteria and Fungi infections by (14), (51), (70) possibly the anaerobic disease-producing classes.

(2) Protozoan Parasites, such as coccidiosis of the bladder (14), (51), (70), a disease caused by the multiplication of a very small protozoan parasite in the tissues of the affected animals, which may be peculiar to cattle, also fluke worms and certain nematodes (71).

(3) Metazoan Parasites, Filaria or Distomata (51) (70), a thread-like parasite of the genus entozoa which often infests animals.

(4) Pentastomes, (Cleland) (25), or Linguatulida, a group of worm-like parasitic arthropods which sometime live in the bodies of the herbivorous animals.
Recorded Theories of Causation (Cont'd).

(5) Nutritional and Metabolic Origin. The poor quality of fodder, such as a diet of coarse pasture grasses occurring at high altitudes in wooded regions; to the lack of albumen in the food (71); mineral deficiencies in the herbage available to the animals (51).

(6) Mineral and Plant Poisoning produced either by the chemical action or the mechanical irritation of various toxic principles or specific chemical constituents of plants ingested or derived from the soil habitat upon which the plants are grown, such as oxalic acid and oxalates (14), (71); salicylates (14); various irritating poisons (70); acid plants (14); bracken plants and spores (14), (20); blackberry (Recumbent), water celery (Oenanthe) clover aftermath (14).

EXPERIMENTAL REPRODUCTION.

(a) By Infection.

The experiments of Hadwen (55)(59) to reproduce the disease by infection or contagion, in which a number of calves were kept in contact with diseased cattle, and attempts to infect them, first by blood inoculation; secondly, by ingestion; thirdly, by inoculating urine; fourthly, by introducing portions of a diseased animal's bladder into that of a healthy one, also siphoning a diseased animal's urine into a healthy animal's bladder, all gave no direct evidence that the disease is of a contagious or infectious nature. Craig and Kehoe (31) confirm the conclusion that the disease has not been transmitted experimentally by inoculation with blood or urine, and Bull, Dickinson and Dann (16A) report negative results obtained by injecting into normal cows the ground up lesions from red water bladders.

(b) By Ingestion.

(1) Bracken and Bracken Spore Feeding.

The prevalence of bracken (Pteris aquilina) in Red Water areas has led many to suspect this plant or its spore to be a causation factor in this disease.

The experiments of Bruce (12) (13), by feeding large amounts of bracken to cattle did not cause poisoning in the animals or reproduce the symptoms of Red Water.
(b) By Ingestion (Cont'd).

(1) Bracken and Bracken Spore Feeding (Cont'd)

Bracken spores, in large quantities, fed in milk to a calf, by Hadwen (56) for eighty-eight days did not indicate any characteristic symptoms and the animal, when killed, at the end of the experiment, showed organs in normal condition.

(2) Oxalic Acid and Oxalates.

Hadwen (56) (57) in 1914 propounded the theory that plants containing oxalic acid were the cause of Haematuria in Cattle. He carried out a series of experiments by injecting large doses of calcium oxalate crystals into the bladder of cattle and by feeding oxalic acid by mouth, and reported results to substantiate his theory.

However, the experiments of Kalkus and Sawyer(77) (78, 79, 80, 81) in feeding oxalic acid to heifers, for over a period of five years (1924 to 1929) in an attempt to produce red water were negative. In 1929, these experimentors started feeding calcium oxalate daily to heifers. However, to date these animals have shown no indication of Red Water.

The results obtained by workers in Australia (Dickinson and Bull(29)) as reported in 1930 "appear to have definitely excluded oxalic acid as being the irritant responsible for the production of lesions in the bladder," characteristic of Red Water.

Also Craig (33) in 1930, reviewing the subject, states that he is unable to confirm the observation of Hadwen.

On the other hand, another approach to this theory is suggested by Datta (35) who believes that Haematuria Vesicalis is a result of faulty metabolism, and that it is due to the elaboration of oxalic acid in the system.

An excess of oxalic acid in the blood and urine presupposes the removal of calcium from the tissues and body fluids. The reductions in the calcium content of the tissues may explain the absence of any tendency of the bladder lesions to heal, thus resulting in the finding of large amounts of clotted blood in the bladder. So that a condition of profuse and uncontrolled bleeding is said to be produced and is
By Ingestion (Cont'd).

due to a calcium deficiency brought about by the oxalates.

(3) Sorrel Feeding.

The disease was not produced by feeding sorrel to cows by Craig and Kehoe (30).

(4) Plant Extracts.

Hadwen (1914) (56) experimented with extracts of three plants, namely, bleeding-heart (Dicentra), deergrass (Achlys triphylla) and alder (Alnus glutinosa, Medic.) by injection into rabbits and guinea-pigs. The doses produced no characteristic symptoms of Red Water.

LOCAL SURVEYS.

(1) Plants.

During the Summer of 1929 Groh (53) made a botanical survey of the lower Fraser Valley. The preliminary report of this survey confirms other previous workers' observation that bracken "has shown more consistent association with the occurrence of the disease than any other plant." Two samples of hay were secured, one from a non-Red Water area and the other sample from a Red Water farm. They were analyzed botanically and it is reported by Shutt (1930) (115) "the results of this analysis are therefore pretty largely negative as regards known injurious species unless bracken can be shown to have any bearing on the matter."

(2) Soils, Water, Etc.

In conjunction with the above survey samples of soil, herbage, well water, blood and urine from diseased cattle were collected and analyzed (115). The data obtained being rather meagre, no positive conclusions could be drawn from this investigation.

(3) Economic.

An economic survey has been made during the past two years by MacKenzie (94) which was made in conjunction with the distribution of a treatment of ground coral rock and sodium bicarbonate. The effects of this treatment as previously reported by Grauer (51) have been satisfactory in a number of cases.
TREATMENTS.

Many drugs together with various tonics and so-called cures have been propounded and administered as treatments for the disease, without permanent recoveries being so far recorded.

Hadwen (54) in 1911 reported that "the most useful drug so far has been calcium lactate; this drug undoubtedly raises the clotting property of the blood, and thus helps clotting in the capillaries of the bladder." In a later report Hadwen (56) (1914) states that in France that "affected animals recovered after a few doses of soda bicarbonate.

Bruce (14) has used a course of treatment consisting of first administering a dose of salts (magnesium sulphate), the animal being tied up, stall fed, and given potassium acetate one-half ounce, twice a day, in its drinking water, this being supplemented with a mixture of calcium lactate, three drams, sodium bicarbonate, three drams, ferric sulphate, 1 dram, fed twice a day on the tongue or in the feed. However, this treatment appears to give only temporary relief.

In respect to the treatment consisting of feeding the mixture of coral rock flour and sodium bicarbonate referred to above, it seems advisable to record at this time some of the history leading up to its first recorded use as a Red Water treatment. It is understood that Dr. E.A. Bruce, Animal Pathologist, stationed at Agassiz, B.C., advocated in an address on Red Water given before a North Western Veterinary Association, meeting in Victoria, B.C., in 1926, the use of an alkaline treatment for this disease. Among those who followed out this suggestion was Dr. A. Hendricksen. He tried it as a substitute for air-slacked lime, mixed with sodium bicarbonate, in treating Red Water cases.

Dr. J.G. Jervis of the University of British Columbia attended this meeting. He adopted the idea and subsequently the Animal Husbandry Department of this University obtained a quantity of the coral rock flour, and mixed one part with two parts of sodium bicarbonate. It was distributed to a large number of farmers, in the affected Fraser Valley area, with encouraging results. A report of this project has been prepared by Mr. J. Cameron MacKenzie, a co-worker at this University (94).

The physiological effect of the alkaline treatments fed may be due to the changed buffer reaction of the
Treatments (Cont'd).

animal's body fluids, assisted by the probable blood-coagulating action of the calcium. Douris and Plessis (39) report that the feeding of certain inorganic and organic calcium salts to the animals has a marked effect on the coagulation of their blood. Palmer et al (104) have found a marked relationship between plasma bicarbonate and urinary acidity following the administration of sodium bicarbonate.

Sherman (114) quotes Meltzer as stating that "Calcium is capable of correcting the disturbances of the inorganic equilibrium in the animal's body, whatever the direction of the deviations from the normal may be. Any abnormal effect which sodium potassium, or magnesium, may produce, whether the abnormality be in the direction of increased irritation or of decreased irritability, calcium is capable of re-establishing the normal equilibrium."

The coagulation of blood is controlled in a large measure by prothrombin, a ferment which brings about fermentation of fiboin from fiboinogen of the blood. Roderick (110) concludes that the failure of blood clotting in cattle, fed a ration high in sweet clover hay, is due to a deficiency of prothrombin. It is possible that the feeds fed to the red water animals may produce a condition in their system creating a deficiency of this ferment.

CHARACTERISTIC SYMPTOMS AND FACTORS.

(a) Lesions in the Bladder.

The formation of the lesions of the bladder as already described and observed by previous workers, may be the result of ingested irritants directly absorbed or elaborated in the animals' system. The locality of these lesions would indicate in a measure their mode of formation, however only a few workers mention their location. Hadwen (1917) (51) says "as a general rule the lesions are most marked at its inferior part." Craig (33) states that "in the urinary bladder the lesions are scattered over the mucous membrane, particularly along the floor." In chronic cases, according to Hadwen (57), Dickinson and Bull (38) cancer has been found to have developed in the bladder, as a result of irritating effect of the causal agent.

In an investigation of the lesions resulting from ingestion of silica, Policard (105) concludes that particles of silica dioxide (SiO₂) are attacked by the cellular juices and the resulting fibrosis with its degenerated cytoplasm is rich in silica. Mills (96) also dealing with the action of siliceous materials on animal tissues, states
that "Siliceous spicules, when introduced into the tissues of animals, are slowly but definitely dissolved, proving conclusively that silica is soluble in the tissue fluids of animals."

The local action of uric acid upon the tissues has been studied by Chini (21) who observed that the injection of uric acid or urates is followed by inflammation of the tissues, similar to foreign body effect and a chemical irritation, with the formation of morbid growth resembling granulation tissue.

Coumarin (1,2 – benzopyrone) when applied directly to mucous membrane is extremely irritant (B.P. C. 1923). Coumarin is a widely distributed substance in the vegetable kingdom, besides being found in the Tonka bean (Dipteryx odorata, Willd.) it is present in Melilotus species (Leguminosae), several grasses, and in some members of the Compositae family of plants. It is present in plants as a glucoside, which is decomposed by a ferment present in the plant. It is only slightly soluble in water, but dissolves more readily in alkaline solutions, and is reprecipitated from them by acids. There is a probability that in a mixture of legumes, grasses and weeds that there may be sufficient coumarin ingested by an animal over a long period of time, to have a cumulative effect, and to cause serious irritation to the mucous membrane of the bladder.

(b) Blood in Urine.

The presence of blood in the urine is probably the most distinctive characteristic symptom of Red Water disease. Assuming that the cause may be a result of the ingestion of material which exerts a toxic or irritant effect upon the bladder epithelium, with the resultant formation of the bleeding lesions; then there are many possible agencies which might be considered. According to Brundage (15) the indication of blood in the urine would suggest the ingestion of Cyclamin, solamin, and other saponin substances, Helvellaic acid and phallin. Plants containing saponins are toxic, as they are powerful protoplasmic poisons so they are strongly irritant. The common corncockle (agrostemnia githago L.) contains a saponin which is absorbed by the subcutaneous tissue and intestines (Allan (3)) Ewart (43) suggests that saponin-containing plants are responsible for certain stock diseases. Lauder (85) also states that "santonin imparts a blood red colour to the urine." Authenrieth (10) describes the behavior of santonin in the organism, and the appearance of a red pigment in the urine after administration to a subject.
Characteristic Symptoms and Factors (Cont'd).

It is well known that several of the inorganic elements that may be ingested with the animals' food will act as irritants. These may exert an injurious effect by absorption in the body fluids, through the principle of osmosis. This process may so modify the cells of some particular body organ as to disturb its normal function in metabolism and ultimately cause inflammation. For instance, lead has a cumulative action in the animal system, eventually producing chronic poisoning and may exert an independent influence upon the blood, upon nutrition and upon the muscular and nervous structure of the animal. The presence of blood in the urine is a typical symptom of lead poisoning (Underhill (121)). Aluminium salts are considered as being toxic to plants, animals and man, by exerting an irritant influence upon the protoplasm. The condition of poisoning in animals is indicated by the presence in the urine of albumin and blood (121).

Vanadium poisoning, sometimes called Vanadiumism, (Dutton (40)), belongs to the nitrogen and phosphorus group, having under certain conditions feebly basic and strong acid properties. In cases of poisoning the urine may contain albumin, casts and blood (Underhill (121)).

Some of the salts of heavy metals, e.g., lead, silver, mercury, copper, zinc and manganese (110), when coming in contact with the protein of cell walls form metal albuminates, which are insoluble, or soluble only in excess of albumin.

\[
\text{Metal SO}_4 + \text{H}_2 \text{Albumin} \rightarrow \text{Metal Albuminate} + 2\text{H}_2 + \text{SO}_4
\]

The resulting irritant effect is ascribed to the acid liberated with the solution of the heavy metals, as a class, hydrolytic dissociation usually occurs, with a marked acidity of the solution.

\[
\text{ZnO}_2 + 2\text{H}_2\text{O} \rightarrow \text{Zn} (\text{OH})_2 + 2\text{HCl}.
\]

The majority of metallic poisons are culminative, and are eliminated through practically all the excretory channels of animals. In ruminants ingested culminative poisons are immensely diluted in the rumen, it being distributed evenly on rumination and generally absorbed with a slow elimination.

The metals are considered as typical irritants and may have a local irritant effect as well as a general effect which may be produced after absorption.
Characteristic Symptoms and Factors (Cont'd).

(c) Reaction of Urine.

The reaction of the urine of normal herbivorous animals is usually alkaline. There seems to be a different opinion respecting this factor in respect to the urine of Red Water cattle. Hadwen (57) states "the reaction of the urine is generally strongly alkaline, but in a few instances the reaction had become neutral owing to the excessive amounts of blood contained in it;" Craig (33) records that "the reaction was usually alkaline, occasionally acid;" Bruce (14) is inclined to consider the urines of affected animals as being abnormal and usually to be acid in reaction, when tested with phenolphthalein, as an indicator; Bull (16) states that they have not found urines from "redwater" farms are more acid than normal. In 1929, thirty samples of fresh urine from affected cows were examined for the hydrogen-ion concentration. It was found that no sample had an acid reaction (Shutt and Robinson (115)). An examination, in 1931, by the author, of six samples of urines from typical red water cows showed an hydrogen-ion concentration indicative of an alkaline reaction.

(d) Blood Conditions.

Investigations have been made, at the University of British Columbia by Allardyce et al (2), of the Blood Normals for Cattle for normal animals and some for pathological animals, and by Fleming et al (44) for animals affected with Red Water in various stages. The findings were, however, negative; in no case were significant variations of the blood constituents apparent from those of normal cattle. The analyses, reported by Shutt and Robinson (115), of samples of blood sera from diseased and unaffected animals indicate that their calcium and phosphorus content are not significantly different from each other and that there is no lack of either of these elements in the blood of redwater animals. Hadwen (54) (57) states that "in the early stages the blood appears normal. The first sign is a variation in the size of the red cells; this is followed by the usual changes seen in secondary anaemia. The clotting property of the blood is generally low."

Blood examinations made, by Craig (33), when the haematuria was severe gave evidence of secondary anaemia in a varying degree; the haemoglobin content was reduced, and the red blood corpuscle count was low.

(e) Age of Animals Affected.

The consensus of opinion of various observers of Red Water affected cattle would indicate that the disease usually
Characteristic Symptoms and Factors (Cont'd).

makes its appearance when the animals are of adult age, the usual range being from five to ten years old, but occasionally appearing in younger animals.

The following table gives a resume of some of the recorded opinions as to the age of the affected animals.

**TABLE V.**

<table>
<thead>
<tr>
<th>Age When Affected</th>
<th>Usual Range Years</th>
<th>Occasional Years</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 6</td>
<td></td>
<td>2</td>
<td>Bruce (14)</td>
</tr>
<tr>
<td>5 and over</td>
<td>under 5</td>
<td></td>
<td>Kerrigan (83)</td>
</tr>
<tr>
<td>9 to 11</td>
<td>4 to 6</td>
<td></td>
<td>Craig &amp; Kehoe (31,32)</td>
</tr>
<tr>
<td>8 to 12</td>
<td>5 or 6</td>
<td></td>
<td>Craig (33)</td>
</tr>
<tr>
<td>2 to 14</td>
<td>2</td>
<td></td>
<td>Hadwen (54,57)</td>
</tr>
<tr>
<td>3 to 6</td>
<td>1</td>
<td></td>
<td>McKee &amp; McKee (93)</td>
</tr>
</tbody>
</table>

The principal reason for reviewing the foregoing data was to obtain an inventory of the knowledge already possessed concerning this disease; and to critically examine and to evaluate this accumulated information as possible evidence in reference to the causation of the disease. A considerable number of references have been examined in order to develop a bibliography relating to the disease, so that a thorough survey of the field could be made to discover the extent to which the problem had already been investigated. It was realized early in this investigation that very little work had been prosecuted in respect to the soils in Red Water areas or to the feeding stuffs fed to Red Water animals, so that by the data that follows some of the questions relative to this line of attack will be recorded and discussed.

**EXPERIMENTAL DATA.**

(a) Survey of Affected Area.

During the Fall months of 1931 a survey was made of a number of typical Red Water farms in conjunction with the economic survey made by MacKenzie (94). During these
Experimental Data (Cont'd).

visits, samples of soils, grass and oat hays, and water were collected. Through the courtesy and assistance of Dr. J.E. Jervis some samples of fresh red-water urines were obtained, and also one specimen of an infected bladder.

(b) Source of Materials.

The samples of soils, hays, and waters referred to above were all composite samples and representative of the material available on the respective farms upon which they were obtained. Some soils were also obtained through the co-operation of Dr. E.A. Bruce of Agassiz, B.C.

(c) Methods of Analysis.

The soil and feed samples were prepared as usual for analysis of this class of material. The methods of analysis used for the soils and feeds were essentially those adopted by the Association of Official Agricultural Chemists (9). The methods of analyses employed for the waters were those approved by the American Public Health Association (4); the urines were examined principally by methods as outlined by Hawk and Bergeim (62).

(d) Analyses of Materials.

(1) Soils, consisting of twenty-four samples, nineteen of these were obtained from Red Water farms and five from disease-free farms in the Fraser Valley.

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>Description</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 B</td>
<td>Brown Sandy</td>
<td>Aldergrove</td>
</tr>
<tr>
<td>2 B</td>
<td>Light Gray Clayey</td>
<td>Rosebank Is. Chilliwack.</td>
</tr>
<tr>
<td>3 B</td>
<td>Brown Sandy</td>
<td>Mount Lehman</td>
</tr>
<tr>
<td>4 B</td>
<td>Sandy Loam</td>
<td>Abbotsford</td>
</tr>
<tr>
<td>6 B</td>
<td>Sandy Loam</td>
<td>Abbotsford</td>
</tr>
<tr>
<td>2 S</td>
<td>Light Sandy</td>
<td>Coglan</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

**TABLE VI. (Cont’d)**

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>Description</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 S</td>
<td>Sandy Loam</td>
<td>Port Haney</td>
</tr>
<tr>
<td>4 S</td>
<td>Sandy Loam</td>
<td>Whonnock</td>
</tr>
<tr>
<td>5 S</td>
<td>Chocolate Loam</td>
<td>Abbotsford</td>
</tr>
<tr>
<td>6 S</td>
<td>Light Brown Sandy</td>
<td>Sardis</td>
</tr>
<tr>
<td>7 S</td>
<td>Light Sandy Loam</td>
<td>Sardis</td>
</tr>
<tr>
<td>8 S</td>
<td>Chocolate Loam</td>
<td>Fort Langley</td>
</tr>
<tr>
<td>9 S</td>
<td>Clay Loam</td>
<td>Mount Lehman</td>
</tr>
<tr>
<td>10 S</td>
<td>Red Clay Loam</td>
<td>Abbotsford</td>
</tr>
<tr>
<td>11 S</td>
<td>Clay Loam</td>
<td>Glen Valley</td>
</tr>
<tr>
<td>12 S</td>
<td>Silty</td>
<td>Milner</td>
</tr>
</tbody>
</table>

**Non-Red Water Farms.**

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>Description</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 S</td>
<td>Clayey Loam</td>
<td>Haney</td>
</tr>
<tr>
<td>14 S 1</td>
<td>Gray Silty</td>
<td>Essondale</td>
</tr>
<tr>
<td>14 S 2</td>
<td>Peaty</td>
<td>Essondale</td>
</tr>
<tr>
<td>15 S</td>
<td>Peaty</td>
<td>Steveston</td>
</tr>
<tr>
<td>16 S</td>
<td>Brown Sandy</td>
<td>Coquitlam</td>
</tr>
</tbody>
</table>

All samples were thoroughly air dried and the material then passed through a 20-mesh per inch sieve used for analysis. The determinations being made on the acid soluble portion, using hydrochloric acid (S.G. 1.115) as the solvent. All figures given are on the moisture free basis and stated as percentage by weight.
Experimental Data (Cont'd)

TABLE VII.

Silica and Organic Content of Soils.

Red Water Farms.

<table>
<thead>
<tr>
<th>Laboratory Number</th>
<th>Total Insoluble Matter</th>
<th>Silica (SiO₂)</th>
<th>Ignition Loss</th>
<th>Nitrogen (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 B</td>
<td>79.11</td>
<td>--</td>
<td>11.79</td>
<td>0.20</td>
</tr>
<tr>
<td>2 B</td>
<td>75.18</td>
<td>--</td>
<td>12.60</td>
<td>0.30</td>
</tr>
<tr>
<td>3 B</td>
<td>77.89</td>
<td>--</td>
<td>11.29</td>
<td>0.18</td>
</tr>
<tr>
<td>4 B</td>
<td>72.63</td>
<td>--</td>
<td>16.85</td>
<td>0.21</td>
</tr>
<tr>
<td>6 B</td>
<td>72.91</td>
<td>--</td>
<td>16.44</td>
<td>0.35</td>
</tr>
<tr>
<td>2 S</td>
<td>78.16</td>
<td>0.34</td>
<td>12.15</td>
<td>0.21</td>
</tr>
<tr>
<td>3 S</td>
<td>74.69</td>
<td>0.38</td>
<td>11.36</td>
<td>0.16</td>
</tr>
<tr>
<td>4 S</td>
<td>72.01</td>
<td>0.28</td>
<td>17.68</td>
<td>0.24</td>
</tr>
<tr>
<td>5 S</td>
<td>75.73</td>
<td>0.42</td>
<td>13.97</td>
<td>0.21</td>
</tr>
<tr>
<td>6 S</td>
<td>79.43</td>
<td>0.31</td>
<td>8.12</td>
<td>0.16</td>
</tr>
<tr>
<td>7 S</td>
<td>80.32</td>
<td>0.30</td>
<td>6.47</td>
<td>0.11</td>
</tr>
<tr>
<td>8 S</td>
<td>74.67</td>
<td>0.38</td>
<td>15.08</td>
<td>0.24</td>
</tr>
<tr>
<td>9 S</td>
<td>73.16</td>
<td>0.82</td>
<td>16.09</td>
<td>0.35</td>
</tr>
<tr>
<td>10 S</td>
<td>74.64</td>
<td>0.82</td>
<td>14.60</td>
<td>0.28</td>
</tr>
<tr>
<td>11 S</td>
<td>78.07</td>
<td>0.52</td>
<td>12.18</td>
<td>0.30</td>
</tr>
<tr>
<td>12 S</td>
<td>72.86</td>
<td>0.82</td>
<td>12.19</td>
<td>0.20</td>
</tr>
<tr>
<td>Average *</td>
<td>75.83</td>
<td>0.49</td>
<td>13.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Range</td>
<td>72.01-80.32</td>
<td>0.28-0.82</td>
<td>6.47-17.68</td>
<td>0.11-0.35</td>
</tr>
</tbody>
</table>

*Not including B Series.
Experimental Data (Cont'd)

TABLE VII. (Cont'd)
Silica and Organic Content of Soils.

Non-Red Water Farms.

<table>
<thead>
<tr>
<th>Laboratory Number</th>
<th>Total Insoluble Matter</th>
<th>Silica (SiO₂)</th>
<th>Ignition Loss</th>
<th>Nitrogen (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 S</td>
<td>62.05</td>
<td>0.21</td>
<td>25.57</td>
<td>0.70</td>
</tr>
<tr>
<td>S 14 S</td>
<td>71.66</td>
<td>0.65</td>
<td>14.69</td>
<td>0.32</td>
</tr>
<tr>
<td>P 14 S</td>
<td>52.46</td>
<td>0.37</td>
<td>42.54</td>
<td>1.20</td>
</tr>
<tr>
<td>15 S</td>
<td>70.57</td>
<td>0.55</td>
<td>19.95</td>
<td>0.67</td>
</tr>
<tr>
<td>16 S</td>
<td>75.15</td>
<td>0.29</td>
<td>17.15</td>
<td>0.36</td>
</tr>
<tr>
<td>Average</td>
<td>66.38</td>
<td>0.41</td>
<td>33.95</td>
<td>0.65</td>
</tr>
<tr>
<td>Range</td>
<td>52.46-75.15</td>
<td>0.21-0.65</td>
<td>14.69-42.54</td>
<td>0.32-1.20</td>
</tr>
</tbody>
</table>

From the above data for Red Water farm soils it will be noted that the total insoluble matter, representing chiefly the insoluble silicates and certain forms of organic matter, is comparatively high; the soluble silica, in the form of soluble silicates is slightly higher in some instances than might be normally expected; the ignition loss, composed principally of organic matter, carbonates, free and interstitial water, and other volatile constituents, is low. These conditions are to be expected in view of the character of the soils, which all tend to be of a sandy nature containing only small amounts of humus.

TABLE VIII.

Ratio of Magnesium and Phosphorus to Calcium in Soils

Red Water Farms.

<table>
<thead>
<tr>
<th>Laboratory Number</th>
<th>Calcium Oxide (CaO)</th>
<th>Magnesium Oxide (MgO)</th>
<th>Phosphates (P₂O₅)</th>
<th>MgO CaO</th>
<th>P₂O₅ CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 B</td>
<td>1.01</td>
<td>1.39</td>
<td>0.34</td>
<td>1.38</td>
<td>0.33</td>
</tr>
<tr>
<td>2 B</td>
<td>1.31</td>
<td>1.16</td>
<td>0.45</td>
<td>0.89</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd)

TABLE VIII (Cont'd)

Ratio of Magnesium and Phosphorus to Calcium in Soils

Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium Oxide (CaO)</th>
<th>Magnesium Oxide (MgO)</th>
<th>Phosphates (P₂O₅)</th>
<th>MgO/CaO</th>
<th>P₂O₅/CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 B</td>
<td>0.98</td>
<td>1.21</td>
<td>0.29</td>
<td>1.24</td>
<td>0.30</td>
</tr>
<tr>
<td>4 B</td>
<td>0.79</td>
<td>0.98</td>
<td>0.24</td>
<td>1.23</td>
<td>0.30</td>
</tr>
<tr>
<td>6 B</td>
<td>0.84</td>
<td>1.10</td>
<td>0.14</td>
<td>1.30</td>
<td>0.17</td>
</tr>
<tr>
<td>2 S</td>
<td>0.75</td>
<td>0.73</td>
<td>0.06</td>
<td>0.97</td>
<td>0.08</td>
</tr>
<tr>
<td>3 S</td>
<td>1.73</td>
<td>1.60</td>
<td>0.13</td>
<td>1.41</td>
<td>0.12</td>
</tr>
<tr>
<td>4 S</td>
<td>0.87</td>
<td>0.36</td>
<td>0.08</td>
<td>0.42</td>
<td>0.09</td>
</tr>
<tr>
<td>5 S</td>
<td>0.68</td>
<td>0.40</td>
<td>0.40</td>
<td>0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>6 S</td>
<td>0.99</td>
<td>0.53</td>
<td>0.27</td>
<td>0.53</td>
<td>0.27</td>
</tr>
<tr>
<td>7 S</td>
<td>1.69</td>
<td>0.51</td>
<td>0.12</td>
<td>0.30</td>
<td>0.07</td>
</tr>
<tr>
<td>8 S</td>
<td>0.60</td>
<td>1.81</td>
<td>0.42</td>
<td>3.04</td>
<td>0.70</td>
</tr>
<tr>
<td>9 S</td>
<td>0.81</td>
<td>1.09</td>
<td>0.09</td>
<td>1.34</td>
<td>0.11</td>
</tr>
<tr>
<td>10 S</td>
<td>0.78</td>
<td>0.54</td>
<td>0.13</td>
<td>0.69</td>
<td>0.17</td>
</tr>
<tr>
<td>11 S</td>
<td>1.00</td>
<td>1.02</td>
<td>0.09</td>
<td>1.02</td>
<td>0.09</td>
</tr>
<tr>
<td>12 S</td>
<td>0.89</td>
<td>1.62</td>
<td>0.07</td>
<td>1.82</td>
<td>0.08</td>
</tr>
<tr>
<td>Average</td>
<td>0.94</td>
<td>1.00</td>
<td>0.21</td>
<td>1.13</td>
<td>0.23</td>
</tr>
<tr>
<td>Range</td>
<td>0.60-1.69</td>
<td>0.36-1.81</td>
<td>0.07-0.45</td>
<td>0.30-3.04</td>
<td>0.08-0.70</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd)

TABLE VIII. (Cont'd)

Ratio of Magnesium and Phosphorus to Calcium in Soils

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium Oxide</th>
<th>Magnesium Oxide</th>
<th>Phosphates (P₂O₅)</th>
<th>MgO</th>
<th>P₂O₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 S</td>
<td>0.89</td>
<td>1.42</td>
<td>0.39</td>
<td>1.59</td>
<td>0.44</td>
</tr>
<tr>
<td>S 14 S</td>
<td>0.95</td>
<td>1.99</td>
<td>0.12</td>
<td>2.09</td>
<td>0.13</td>
</tr>
<tr>
<td>P 14 S</td>
<td>1.13</td>
<td>0.94</td>
<td>0.22</td>
<td>0.83</td>
<td>0.19</td>
</tr>
<tr>
<td>15 S</td>
<td>1.01</td>
<td>1.45</td>
<td>0.20</td>
<td>1.44</td>
<td>0.19</td>
</tr>
<tr>
<td>16 S</td>
<td>0.72</td>
<td>0.49</td>
<td>0.13</td>
<td>0.67</td>
<td>0.18</td>
</tr>
<tr>
<td>Average</td>
<td>0.94</td>
<td>1.26</td>
<td>0.21</td>
<td>1.32</td>
<td>0.23</td>
</tr>
<tr>
<td>Range</td>
<td>0.56-</td>
<td>0.94-</td>
<td>0.12-</td>
<td>0.67-</td>
<td>0.13-</td>
</tr>
<tr>
<td></td>
<td>1.13</td>
<td>1.45</td>
<td>0.39</td>
<td>2.93</td>
<td>0.44</td>
</tr>
</tbody>
</table>

The lime content of the soils is not abnormally low, and its relation to the magnesium content is within a safe range. An excess of magnesium is considered toxic to higher plants, particularly when the Ca-Mg Ratio is greater than three. (Loew (80)). The phosphates are deficient when compared with the minimum of 0.4 per cent for acid soils, found, by Truog (120), to be required for this element in crop production. Harris (60) quotes the results of several workers to show that the phosphorus content of acid soils is generally low and largely unavailable for use by plants. The explanation is offered that acid soils convert any calcium phosphate that may be present into soluble compounds which are either washed out or are fixed in an insoluble form by the formation of iron and aluminium phosphates. This deficiency is evidently one of the limiting factors for the assimilation of the other minerals by the plants grown on these soils. It is most probable that the addition of the proper phosphatic fertilizers to these soils would not only increase the percentage of phosphorus but also of the calcium content in the plants grown on them.
**Experimental Data (Cont'd).**

**TABLE IX.**

Ratios between Calcium and Iron and Aluminium in Soils.

**Red Water Farms.**

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium Oxide</th>
<th>Iron Oxide</th>
<th>Aluminium Oxide</th>
<th>$\frac{Fe_2O_3}{CaO}$</th>
<th>$\frac{Al_2O_3}{CaO}$</th>
<th>$\frac{Fe_2O_3 + Al_2O_3}{CaO}$</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1B</td>
<td>1.01</td>
<td>4.74</td>
<td>5.45</td>
<td>4.71</td>
<td>5.42</td>
<td>10.13</td>
<td>5.50</td>
</tr>
<tr>
<td>2B</td>
<td>1.31</td>
<td>4.92</td>
<td>6.46</td>
<td>3.76</td>
<td>4.94</td>
<td>8.70</td>
<td>5.54</td>
</tr>
<tr>
<td>3B</td>
<td>0.98</td>
<td>4.65</td>
<td>6.19</td>
<td>4.75</td>
<td>6.06</td>
<td>11.08</td>
<td>5.53</td>
</tr>
<tr>
<td>4B</td>
<td>0.79</td>
<td>5.19</td>
<td>8.65</td>
<td>6.60</td>
<td>11.00</td>
<td>17.61</td>
<td>4.53</td>
</tr>
<tr>
<td>6B</td>
<td>0.84</td>
<td>3.65</td>
<td>8.62</td>
<td>5.68</td>
<td>13.41</td>
<td>19.09</td>
<td>4.66</td>
</tr>
<tr>
<td>2S</td>
<td>0.75</td>
<td>4.86</td>
<td>5.86</td>
<td>6.50</td>
<td>7.83</td>
<td>14.33</td>
<td>5.58</td>
</tr>
<tr>
<td>3S</td>
<td>1.13</td>
<td>5.55</td>
<td>7.25</td>
<td>4.90</td>
<td>6.40</td>
<td>11.29</td>
<td>4.12</td>
</tr>
<tr>
<td>4S</td>
<td>0.87</td>
<td>4.49</td>
<td>7.52</td>
<td>5.18</td>
<td>8.67</td>
<td>13.85</td>
<td>4.80</td>
</tr>
<tr>
<td>5S</td>
<td>0.68</td>
<td>4.23</td>
<td>7.24</td>
<td>6.27</td>
<td>10.72</td>
<td>16.97</td>
<td>4.62</td>
</tr>
<tr>
<td>6S</td>
<td>0.99</td>
<td>4.85</td>
<td>5.86</td>
<td>4.87</td>
<td>5.88</td>
<td>10.75</td>
<td>5.13</td>
</tr>
<tr>
<td>7S</td>
<td>1.69</td>
<td>4.84</td>
<td>4.77</td>
<td>2.86</td>
<td>2.82</td>
<td>5.67</td>
<td>4.09</td>
</tr>
<tr>
<td>8S</td>
<td>0.60</td>
<td>5.21</td>
<td>6.23</td>
<td>8.75</td>
<td>9.99</td>
<td>19.21</td>
<td>3.83</td>
</tr>
<tr>
<td>9S</td>
<td>0.81</td>
<td>5.05</td>
<td>7.11</td>
<td>6.23</td>
<td>8.78</td>
<td>15.01</td>
<td>4.07</td>
</tr>
<tr>
<td>10S</td>
<td>0.78</td>
<td>4.96</td>
<td>7.17</td>
<td>6.36</td>
<td>9.19</td>
<td>15.55</td>
<td>4.67</td>
</tr>
<tr>
<td>11S</td>
<td>1.00</td>
<td>3.35</td>
<td>6.07</td>
<td>3.35</td>
<td>6.07</td>
<td>9.42</td>
<td>3.99</td>
</tr>
<tr>
<td>12S</td>
<td>0.89</td>
<td>4.76</td>
<td>10.19</td>
<td>5.35</td>
<td>11.45</td>
<td>16.81</td>
<td>4.00</td>
</tr>
<tr>
<td>Average</td>
<td>0.94</td>
<td>4.58</td>
<td>6.91</td>
<td>5.38</td>
<td>8.16</td>
<td>13.46</td>
<td>4.67</td>
</tr>
<tr>
<td>Range</td>
<td>0.60-1.69</td>
<td>3.35-5.55</td>
<td>5.45-8.65</td>
<td>2.86-2.82</td>
<td>5.67-19.09</td>
<td>3.83-5.58</td>
<td></td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

TABLE IX. (Cont'd)

Ratios between Calcium and Iron and Aluminium in Soils.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium Oxide</th>
<th>Iron Oxide</th>
<th>Aluminium Oxide</th>
<th>Fe₂O₃</th>
<th>Al₂O₃</th>
<th>Fe₂O₃+Al₂O₃</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>13S</td>
<td>0.89</td>
<td>5.31</td>
<td>8.25</td>
<td>5.97</td>
<td>9.27</td>
<td>15.22</td>
<td>3.66</td>
</tr>
<tr>
<td>14S₁</td>
<td>0.95</td>
<td>5.18</td>
<td>8.06</td>
<td>5.45</td>
<td>8.48</td>
<td>13.94</td>
<td>4.33</td>
</tr>
<tr>
<td>14S₂</td>
<td>1.13</td>
<td>2.63</td>
<td>6.38</td>
<td>2.33</td>
<td>5.64</td>
<td>7.97</td>
<td>4.08</td>
</tr>
<tr>
<td>15S</td>
<td>1.01</td>
<td>3.60</td>
<td>5.95</td>
<td>3.56</td>
<td>5.89</td>
<td>9.46</td>
<td>5.04</td>
</tr>
<tr>
<td>16S</td>
<td>0.72</td>
<td>3.21</td>
<td>6.20</td>
<td>4.46</td>
<td>8.61</td>
<td>13.07</td>
<td>5.28</td>
</tr>
<tr>
<td>Average</td>
<td>0.94</td>
<td>3.98</td>
<td>6.97</td>
<td>4.35</td>
<td>7.58</td>
<td>11.93</td>
<td>4.48</td>
</tr>
</tbody>
</table>

The hydrogen ion concentration values indicated that all these Red Water soils are acidic and the ratios between the calcium, iron and aluminium would suggest that the cause of the acidity of these soils probably due to the existence of iron and aluminium compounds which are held absorbed by the soil colloids (Spurway (117)) and associated with the silicates.

The soil conditions, found on these Red Water farms, are undoubtedly the result of the influence of two important climatic factors, namely, rainfall and temperature. The leaching of calcium, thus causing an acid reaction of the soil and the probable formation of insoluble salts of phosphates with manganese and iron. According to Teakle (117A) a soil with a pH below 6.0 will hold its phosphorus in combination with manganese. Holtz (67) in his work on the soil series of Western Washington, which are similar soils to those found in the Fraser Valley area, makes a significant statement in respect to the feeds grown on these soils, that in some instances "cows remained normal until they were turned out on virgin cut-over-land pasture where within a year's time they developed Red Water."
Experimental Data (Cont’d).

(2) Feeding Stuffs.

All samples were collected from various parts of the mows, thoroughly mixed, air dried, and ground to a uniform fineness. As bracken has been prominently mentioned and observed associated with Red Water farms, a sample was obtained and examined in a similar manner to the feeding stuffs. This plant was found more or less present in all samples of hays. The figures given are on the moisture free basis and in percentages by weight.

**TABLE X.**

Reference Description of Mixed Hays.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Description</th>
<th>Locality Grown</th>
</tr>
</thead>
<tbody>
<tr>
<td>01H</td>
<td>Timothy &amp; Clover</td>
<td>Aldergrove</td>
</tr>
<tr>
<td>02H</td>
<td>Timothy and Clover</td>
<td>Goglan</td>
</tr>
<tr>
<td>03H</td>
<td>Mixed Grasses</td>
<td>Port Haney</td>
</tr>
<tr>
<td>04H1</td>
<td>Orchard Grass, Red Clover and Perennial Rye Grass</td>
<td>Whonnock</td>
</tr>
<tr>
<td>04H2</td>
<td>Red Clover</td>
<td>Whonnock</td>
</tr>
<tr>
<td>05H</td>
<td>Grasses and Clover</td>
<td>Abbotsford</td>
</tr>
<tr>
<td>06H</td>
<td>Timothy and Clover</td>
<td>Sardis</td>
</tr>
<tr>
<td>07H</td>
<td>Timothy and Clover</td>
<td>Sardis</td>
</tr>
<tr>
<td>08H</td>
<td>Clover</td>
<td>Fort Langley</td>
</tr>
<tr>
<td>09H</td>
<td>Mixed Grasses</td>
<td>Mount Lehman</td>
</tr>
<tr>
<td>010H</td>
<td>Red Clover, Alsike Timothy, Perennial Rye Grass</td>
<td>Abbotsford</td>
</tr>
<tr>
<td>011H</td>
<td>Mixed Grasses</td>
<td>Glen Valley</td>
</tr>
<tr>
<td>012H1</td>
<td>Grasses and Clover (1930 Crop)</td>
<td>Milner</td>
</tr>
<tr>
<td>012H2</td>
<td>Grasses and Clover (1931 Crop)</td>
<td>Milner</td>
</tr>
</tbody>
</table>
### Experimental Data (Cont'd).

**TABLE X. (Cont'd)**

Reference Description of Mixed Hays.

#### Non-Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Description</th>
<th>Locality Grown</th>
</tr>
</thead>
<tbody>
<tr>
<td>013H</td>
<td>Grasses and Clover</td>
<td>Haney</td>
</tr>
<tr>
<td>014H₁</td>
<td>Grasses and Clover</td>
<td>Essondale</td>
</tr>
<tr>
<td>014H₂</td>
<td>Pasture Clippings</td>
<td>Essondale</td>
</tr>
<tr>
<td>015H</td>
<td>Mixed Grasses</td>
<td>Steveston</td>
</tr>
<tr>
<td>01B</td>
<td>Bracken Fern</td>
<td>Point Grey</td>
</tr>
</tbody>
</table>

*Oat Hay also obtained from these farms.*

**TABLE XI.**

Mixed Hays.

Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Ash</th>
<th>Sand</th>
<th>Soluble Silica (SiO₂)</th>
<th>Iron (Fe₂O₃)</th>
<th>Aluminium (Al₂O₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01H</td>
<td>5.88</td>
<td>0.14</td>
<td>1.17</td>
<td>0.11</td>
<td>0.57</td>
</tr>
<tr>
<td>02H</td>
<td>5.09</td>
<td>0.24</td>
<td>1.91</td>
<td>0.09</td>
<td>0.67</td>
</tr>
<tr>
<td>03H</td>
<td>5.66</td>
<td>0.49</td>
<td>2.39</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>04H₁</td>
<td>5.53</td>
<td>0.09</td>
<td>1.34</td>
<td>0.08</td>
<td>0.68</td>
</tr>
<tr>
<td>04H₂</td>
<td>5.10</td>
<td>0.16</td>
<td>0.69</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>05H</td>
<td>7.24</td>
<td>0.15</td>
<td>1.40</td>
<td>0.21</td>
<td>1.76</td>
</tr>
<tr>
<td>06H</td>
<td>7.78</td>
<td>0.89</td>
<td>2.08</td>
<td>0.18</td>
<td>0.31</td>
</tr>
<tr>
<td>07H</td>
<td>8.23</td>
<td>0.45</td>
<td>0.76</td>
<td>0.16</td>
<td>1.41</td>
</tr>
<tr>
<td>08H</td>
<td>7.13</td>
<td>0.23</td>
<td>0.93</td>
<td>0.11</td>
<td>1.54</td>
</tr>
<tr>
<td>09H</td>
<td>5.66</td>
<td>0.61</td>
<td>1.51</td>
<td>0.09</td>
<td>0.78</td>
</tr>
<tr>
<td>010H</td>
<td>7.21</td>
<td>0.09</td>
<td>0.91</td>
<td>0.06</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

TABLE XI.
Mixed Hays.
Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Ash</th>
<th>Sand</th>
<th>Soluble Silica (SiO₂)</th>
<th>Iron (Fe₂O₃)</th>
<th>Aluminium (Al₂O₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>011H</td>
<td>5.51</td>
<td>0.15</td>
<td>1.02</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>012H₁</td>
<td>6.50</td>
<td>0.91</td>
<td>0.89</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>012H₂</td>
<td>6.33</td>
<td>0.60</td>
<td>1.08</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Average</td>
<td>6.35</td>
<td>0.37</td>
<td>1.29</td>
<td>0.10</td>
<td>0.58</td>
</tr>
<tr>
<td>Range</td>
<td>5.09-8.23</td>
<td>0.09-0.91</td>
<td>0.69-2.39</td>
<td>0.05-0.21</td>
<td>0.03-1.76</td>
</tr>
</tbody>
</table>

Non-Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Ash</th>
<th>Sand</th>
<th>Soluble Silica (SiO₂)</th>
<th>Iron (Fe₂O₃)</th>
<th>Aluminium (Al₂O₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>013H</td>
<td>5.40</td>
<td>0.18</td>
<td>1.44</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>014H₁</td>
<td>6.68</td>
<td>1.30</td>
<td>0.86</td>
<td>0.07</td>
<td>0.14</td>
</tr>
<tr>
<td>014H₂</td>
<td>4.72</td>
<td>0.10</td>
<td>0.64</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>015H</td>
<td>7.16</td>
<td>1.85</td>
<td>0.92</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>Average</td>
<td>5.99</td>
<td>0.86</td>
<td>0.96</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>Range</td>
<td>5.40-7.16</td>
<td>0.10-1.85</td>
<td>0.64-1.44</td>
<td>0.07-0.08</td>
<td>0.06-0.14</td>
</tr>
</tbody>
</table>

Bracken.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Ash</th>
<th>Sand</th>
<th>Soluble Silica (SiO₂)</th>
<th>Iron (Fe₂O₃)</th>
<th>Aluminium (Al₂O₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01B</td>
<td>6.97</td>
<td>0.07</td>
<td>0.69</td>
<td>0.03</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

**TABLE XII.**

**Oat Hay**

**Red Water Farms.**

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Ash</th>
<th>Sand</th>
<th>Soluble Silica ((SiO_2))</th>
<th>Iron ((Fe_2O_3))</th>
<th>Aluminium ((Al_2O_3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>4.31</td>
<td>0.22</td>
<td>1.28</td>
<td>0.14</td>
<td>0.12</td>
</tr>
<tr>
<td>020</td>
<td>4.87</td>
<td>0.55</td>
<td>1.58</td>
<td>0.08</td>
<td>0.42</td>
</tr>
<tr>
<td>060</td>
<td>5.36</td>
<td>0.46</td>
<td>1.66</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>070</td>
<td>7.40</td>
<td>0.88</td>
<td>2.66</td>
<td>0.18</td>
<td>0.83</td>
</tr>
<tr>
<td>080</td>
<td>7.86</td>
<td>0.75</td>
<td>2.23</td>
<td>0.28</td>
<td>0.96</td>
</tr>
<tr>
<td>010 0</td>
<td>6.56</td>
<td>0.60</td>
<td>1.23</td>
<td>0.17</td>
<td>0.11</td>
</tr>
</tbody>
</table>

**Average**

6.06 | 0.58 | 1.77 | 0.17 | 0.43 |

**Range**

4.31 - 7.86 | 0.22 - 0.88 | 1.23 - 2.66 | 0.08 - 0.28 | 0.11 - 0.96 |

It is to be noted that the soluble silica is comparatively high and that the aluminium content seems abnormal on the Red Water farms, their range being wider than those on non-Red Water farms. In view of the opinions already quoted these two constituents may be significant factors in this disease.

**TABLE XIII.**

**Mixed Hays.**

**Red Water Farms.**

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium ((CaO))</th>
<th>Magnesium ((MgO))</th>
<th>Phosphates ((P_2O_5))</th>
<th>Sulphates ((SO_3))</th>
<th>Manganese ((Mn_3O_4))</th>
</tr>
</thead>
<tbody>
<tr>
<td>01H</td>
<td>1.17</td>
<td>0.48</td>
<td>0.41</td>
<td>0.13</td>
<td>0.0104</td>
</tr>
<tr>
<td>02H</td>
<td>0.66</td>
<td>0.26</td>
<td>0.30</td>
<td>0.17</td>
<td>0.0098</td>
</tr>
<tr>
<td>03H</td>
<td>0.60</td>
<td>0.25</td>
<td>0.43</td>
<td>0.20</td>
<td>0.0078</td>
</tr>
<tr>
<td>04H_1</td>
<td>0.53</td>
<td>0.35</td>
<td>0.40</td>
<td>0.17</td>
<td>0.0074</td>
</tr>
<tr>
<td>04H_2</td>
<td>0.91</td>
<td>0.35</td>
<td>0.34</td>
<td>0.18</td>
<td>0.0085</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

**TABLE XIII.**

**Mixed Hays.**

**Red Water Farms.**

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Phosphates (P₂O₅)</th>
<th>Sulphates (SO₃)</th>
<th>Manganese (Mn₃O₄)</th>
</tr>
</thead>
<tbody>
<tr>
<td>05H</td>
<td>1.67</td>
<td>0.55</td>
<td>0.53</td>
<td>0.26</td>
<td>0.0050</td>
</tr>
<tr>
<td>06H</td>
<td>1.27</td>
<td>0.42</td>
<td>0.68</td>
<td>0.37</td>
<td>0.0052</td>
</tr>
<tr>
<td>07H</td>
<td>2.03</td>
<td>0.52</td>
<td>0.51</td>
<td>0.30</td>
<td>0.0049</td>
</tr>
<tr>
<td>08H</td>
<td>1.39</td>
<td>0.54</td>
<td>0.52</td>
<td>0.17</td>
<td>0.0084</td>
</tr>
<tr>
<td>09H</td>
<td>0.98</td>
<td>0.46</td>
<td>0.35</td>
<td>0.26</td>
<td>0.0181</td>
</tr>
<tr>
<td>010H</td>
<td>1.47</td>
<td>0.57</td>
<td>0.51</td>
<td>0.23</td>
<td>0.0075</td>
</tr>
<tr>
<td>011H</td>
<td>0.75</td>
<td>0.45</td>
<td>0.40</td>
<td>0.25</td>
<td>0.0114</td>
</tr>
<tr>
<td>012H₁</td>
<td>0.99</td>
<td>0.59</td>
<td>0.40</td>
<td>0.18</td>
<td>0.0083</td>
</tr>
<tr>
<td>012H₂</td>
<td>1.01</td>
<td>0.51</td>
<td>0.45</td>
<td>0.22</td>
<td>0.0123</td>
</tr>
<tr>
<td>Average</td>
<td>1.12</td>
<td>0.46</td>
<td>0.44</td>
<td>0.25</td>
<td>0.0096</td>
</tr>
<tr>
<td>Range</td>
<td>0.53-</td>
<td>0.25-</td>
<td>0.30-</td>
<td>0.17-</td>
<td>0.0049-</td>
</tr>
<tr>
<td></td>
<td>2.03</td>
<td>0.59</td>
<td>0.68</td>
<td>0.37</td>
<td>0.0181</td>
</tr>
</tbody>
</table>

**Non-Red Water Farms.**

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Phosphates (P₂O₅)</th>
<th>Sulphates (SO₃)</th>
<th>Manganese (Mn₃O₄)</th>
</tr>
</thead>
<tbody>
<tr>
<td>013H</td>
<td>0.74</td>
<td>0.37</td>
<td>0.39</td>
<td>0.28</td>
<td>0.0148</td>
</tr>
<tr>
<td>014H₁</td>
<td>0.96</td>
<td>0.54</td>
<td>0.50</td>
<td>0.45</td>
<td>0.0107</td>
</tr>
<tr>
<td>014H₂</td>
<td>0.48</td>
<td>0.43</td>
<td>0.41</td>
<td>0.26</td>
<td>0.0294</td>
</tr>
<tr>
<td>015H</td>
<td>1.33</td>
<td>0.78</td>
<td>0.52</td>
<td>0.44</td>
<td>0.0161</td>
</tr>
<tr>
<td>Average</td>
<td>0.88</td>
<td>0.53</td>
<td>0.45</td>
<td>0.36</td>
<td>0.0177</td>
</tr>
<tr>
<td>Range</td>
<td>0.48-</td>
<td>0.37-</td>
<td>0.39-</td>
<td>0.26-</td>
<td>0.0107-</td>
</tr>
<tr>
<td></td>
<td>1.33</td>
<td>0.78</td>
<td>0.52</td>
<td>0.45</td>
<td>0.0294</td>
</tr>
</tbody>
</table>

**Bracken.**

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Phosphates (P₂O₅)</th>
<th>Sulphates (SO₃)</th>
<th>Manganese (Mn₃O₄)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01B</td>
<td>0.37</td>
<td>0.44</td>
<td>0.61</td>
<td>0.58</td>
<td>0.0114</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

TABLE XIV.
Oat Hays.
Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Phosphates (P₂O₅)</th>
<th>Sulphates (SO₃)</th>
<th>Manganese (Mn₃O₄)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 0</td>
<td>0.04</td>
<td>0.24</td>
<td>0.35</td>
<td>0.18</td>
<td>0.0076</td>
</tr>
<tr>
<td>02 0</td>
<td>0.23</td>
<td>0.21</td>
<td>0.40</td>
<td>0.16</td>
<td>0.0029</td>
</tr>
<tr>
<td>06 0</td>
<td>0.83</td>
<td>0.33</td>
<td>0.49</td>
<td>0.20</td>
<td>0.0055</td>
</tr>
<tr>
<td>07 0</td>
<td>0.51</td>
<td>0.35</td>
<td>0.65</td>
<td>0.13</td>
<td>0.0068</td>
</tr>
<tr>
<td>08 0</td>
<td>0.58</td>
<td>0.34</td>
<td>0.63</td>
<td>0.19</td>
<td>0.0091</td>
</tr>
<tr>
<td>010 0</td>
<td>0.41</td>
<td>0.40</td>
<td>0.59</td>
<td>0.16</td>
<td>0.0068</td>
</tr>
</tbody>
</table>

Average 0.43  0.31  0.52  0.17  0.0064

Range 0.23-  0.21-  0.35-  0.13-  0.0029-
       0.83    0.40    0.65    0.20    0.0091

The calcium content of the feeding stuffs grown on Red Water farms is comparatively high and has a wider range than on the disease-free farms, the manganese content is distinctly lower in the majority of cases. The physiological effect of this slight deficiency may be of importance, as manganese is now considered an essential element of plant growth and functions in the synthesis of chlorophyll. It occurs in the ash of oxidizing enyzms and so probably assists in the process of oxidation in animal nutrition.

(3) Waters.

These samples were composite ones taken from all sources of supply used by the animals on the respective farms. The figures are stated in parts per million.
Experimental Data (Cont’d).

### TABLE XV.

**Reference Description of Waters.**

#### Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Source</th>
<th>Locality of Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>001 W</td>
<td>Surface and well</td>
<td>Coglan</td>
</tr>
<tr>
<td>002 W</td>
<td>Well near barn</td>
<td>Coglan</td>
</tr>
<tr>
<td>003 W</td>
<td>Running Streams</td>
<td>Port Haney</td>
</tr>
<tr>
<td>004 W</td>
<td>Well</td>
<td>Whonnock</td>
</tr>
<tr>
<td>005 W</td>
<td>Well</td>
<td>Abbottsford</td>
</tr>
<tr>
<td>006 W</td>
<td>Well</td>
<td>Sardis</td>
</tr>
<tr>
<td>007 W</td>
<td>Well</td>
<td>Sardis</td>
</tr>
<tr>
<td>0010 W</td>
<td>Piped Spring</td>
<td>Abbottsford</td>
</tr>
</tbody>
</table>

#### Non-Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>0013 W</td>
<td>Piped Hillside Spring</td>
</tr>
</tbody>
</table>

### TABLE XVI.

**Mineral Content of Waters.**

#### Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Solids</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Silica (SiO₂)</th>
<th>Chlorine (Cl)</th>
<th>Sulphates (SO₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001 W</td>
<td>44.0</td>
<td>7.1</td>
<td>3.5</td>
<td>4.6</td>
<td>3.5</td>
<td>0.3</td>
</tr>
<tr>
<td>002 W</td>
<td>200.0</td>
<td>30.3</td>
<td>29.6</td>
<td>15.4</td>
<td>16.6</td>
<td>5.8</td>
</tr>
<tr>
<td>003 W</td>
<td>77.0</td>
<td>5.7</td>
<td>4.6</td>
<td>9.2</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>004 W</td>
<td>45.0</td>
<td>5.7</td>
<td>2.6</td>
<td>5.3</td>
<td>4.2</td>
<td>1.1</td>
</tr>
<tr>
<td>005 W</td>
<td>74.0</td>
<td>14.3</td>
<td>4.3</td>
<td>12.4</td>
<td>5.1</td>
<td>1.0</td>
</tr>
<tr>
<td>006 W</td>
<td>72.0</td>
<td>11.4</td>
<td>4.5</td>
<td>12.4</td>
<td>2.6</td>
<td>0.1</td>
</tr>
<tr>
<td>007 W</td>
<td>72.0</td>
<td>21.1</td>
<td>3.4</td>
<td>7.0</td>
<td>2.9</td>
<td>1.0</td>
</tr>
<tr>
<td>0010 W</td>
<td>46.0</td>
<td>5.3</td>
<td>1.1</td>
<td>4.2</td>
<td>3.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Average</td>
<td>78.9</td>
<td>12.6</td>
<td>6.7</td>
<td>8.6</td>
<td>5.2</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Experimental Data (Cont'd).

TABLE XVI.

Mineral Content of Waters.
Non-Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Total Solids</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Silica (SiO₂)</th>
<th>Chlorine (Cl)</th>
<th>Sulphates (SO₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0013W</td>
<td>66.0</td>
<td>7.4</td>
<td>3.9</td>
<td>9.8</td>
<td>2.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

The above analyses of the water supplies of these farms indicate that none of them are of a highly mineralized character, and do not contain any element in quantities that might be considered detrimental to the cattle using them.

(4) Urines.

The samples of urine were obtained by catheterizing the animals, and preserved by the addition of a small quantity of toluene.

TABLE XVII.

Urines.
Red Water Animals.
(Grams per litre).

<table>
<thead>
<tr>
<th>Laboratory Number</th>
<th>Specific Gravity</th>
<th>Silica (SiO₂)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 U</td>
<td>1.0093</td>
<td>0.128</td>
<td>8.03</td>
</tr>
<tr>
<td>2 U</td>
<td>1.0160</td>
<td>0.088</td>
<td>7.99</td>
</tr>
<tr>
<td>3 U</td>
<td>1.0288</td>
<td>0.078</td>
<td>7.75</td>
</tr>
<tr>
<td>4 U</td>
<td>1.0348</td>
<td>0.269</td>
<td>7.94</td>
</tr>
<tr>
<td>5 U</td>
<td>1.0164</td>
<td>0.277</td>
<td>8.33</td>
</tr>
<tr>
<td>Average</td>
<td>1.0210</td>
<td>0.168</td>
<td>8.01</td>
</tr>
<tr>
<td>Range</td>
<td>1.0093-1.0348</td>
<td>0.078-0.277</td>
<td>7.75-8.33</td>
</tr>
</tbody>
</table>

The specific gravity of these samples varies within a wide range, but the figures are comparable to those obtained by Bull, Dickinson and Dann(16A), their data are summarized as follows:-
Experimental Data (Cont'd).

Normal Cattle:- Mean 1.033 (Range 1.015 to 1.047)
Red Water Cattle : Mean 1.028 (Range 1.014 to 1.043)

The silica content may be significant when considered in conjunction with the silica content of the herbage produced on the Red Water farms. Forbes et al (46) (48) in their work on the mineral metabolism of the milch cow, have demonstrated the existence of an extensive metabolism of silica; and the retention of this element, from rations containing large quantities of timothy hay, being surprisingly large, silica being found in considerable quantities in the urine, but not in weighable amounts in milk.

The hydrogen ion concentration of these urines show them all to be with an alkaline reaction. Bull et al (16A) report that the pH of Red Water urines was usually between 7.6 and 8.1, and the pH of the normal urines was usually between 7.7 and 8.1; the data recorded by Shutt and Robinson (115) give the following ranges:

Red Water Cattle from 7.15 to 8.40
Normal Cattle from 7.15 to 8.64.

So that the figures recorded above may be considered normal in respect to this reaction.

(5) Bladder.

This specimen was obtained from a cow which had been affected with the disease for some considerable time. A portion showing characteristic lesions was dried to constant weight and ashed. The figures given are on the moisture free basis and are stated as percentage by weight.

<table>
<thead>
<tr>
<th>Mineral Content of Bladder.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Number...........</td>
</tr>
<tr>
<td>Total Ash....................</td>
</tr>
<tr>
<td>Original</td>
</tr>
<tr>
<td>Total Silica (SiO₂)..........</td>
</tr>
<tr>
<td>Calcium (CaO)................</td>
</tr>
<tr>
<td>Magnesium (MgO).............</td>
</tr>
<tr>
<td>Phosphates (PO₄)............</td>
</tr>
<tr>
<td>Sulphates (SO₃).............</td>
</tr>
</tbody>
</table>

These data are interesting because the silica content may be significant, but no definite conclusions can be made until compared with the disease free material.
Experimental Data (Cont'd).

TABLE XIX.
Coral Rock Flour.

<table>
<thead>
<tr>
<th>Laboratory Number</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>0.26</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>44.63</td>
</tr>
<tr>
<td>Silica (Si O₂)</td>
<td>0.34</td>
</tr>
<tr>
<td>Mixed Oxides (R₂O₃)</td>
<td>0.56</td>
</tr>
<tr>
<td>Sulphates (SO₃)</td>
<td>0.30</td>
</tr>
<tr>
<td>Calcium Oxide (CaO)</td>
<td>50.66</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>3.55</td>
</tr>
<tr>
<td>Nitrogen (NH₃)</td>
<td>0.045</td>
</tr>
</tbody>
</table>

TABLE XX.
Comparative Composition
Coral Rock Flour and Coral.

<table>
<thead>
<tr>
<th></th>
<th>Coral Rock Flour</th>
<th>Red Coral</th>
<th>Black Coral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Carbonate (CaO₃)</td>
<td>90.04</td>
<td>86.974</td>
<td>85.801</td>
</tr>
<tr>
<td>Magnesium Carbonate (MgO₃)</td>
<td>7.01</td>
<td>6.804</td>
<td>6.770</td>
</tr>
<tr>
<td>Calcium Sulphate (CaSO₄)</td>
<td>0.51</td>
<td>1.271</td>
<td>1.400</td>
</tr>
<tr>
<td>Ferrous Oxide (FeO)</td>
<td>--</td>
<td>1.720</td>
<td>0.800</td>
</tr>
<tr>
<td>Mixed Oxides (R₂O₃)</td>
<td>0.56</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Phosphoric Acid (P₂O₅)</td>
<td>--</td>
<td>1.331</td>
<td>1.559</td>
</tr>
<tr>
<td>Silica (SiO₂) etc.</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>0.34</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.26</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.04</td>
<td>99.450</td>
<td>96.930</td>
</tr>
</tbody>
</table>

The coral rock flour is probably of marine origin. It was examined for the presence of calcium carbonate in the form of aragonite by the tests discovered by W. Meigen as reported by Clarke (22), who states that "in studying the formation of shell limestone or coral rock, it is desirable to take account of the fact that calcium carbonate exists in at least two geologically important modifications - calcite and aragonite.

It is probable that the calcium carbonate contained in this material is valuable as a source of calcium in the Coral Rock Flour - Soda Bicarbonate treatment.
Experimental Data (Cont'd).

(e) General Discussion of Results.

The experimental data obtained may be considered as fairly representative of the composition of the material examined, although the results may be interpreted as only suggestive of a probable explanation they may upon further investigation lead to the causative factor of this disease.

The soils may be rated as being of a poor quality and need to be improved by a proper system of cultivation and fertilization; the composition of the feeding stuffs is a reflection on the soil conditions. It is, however, possible that the silica content of the feeds may be abnormal and be an important factor in the causation of this disease, together with the high aluminium content. The manganese content may be considered as a possible factor, especially as it may function in the synthesis of chlorophyll and be present in an inorganic form, which during the process of metabolism within the animal may cause abnormal conditions.

However, the data now presented by this work may well be considered as a definite advance in solving the problem, and it is hoped will lead to further investigations along similar lines.

It seems important that the inorganic composition of a large number of samples of urines, and bladders should be examined; also the examination of the flesh and milk of diseased animals might be included, because it is believed that such information would throw considerable light upon this problem.

(f) Practical Considerations and Recommendations.

The following suggestions are offered with the belief that with a change in the practice and system of farming, in the Red Water area of British Columbia, there will be a decided lowering of the incident of the disease.

1. The cultivation of pasture lands every two or three years, in order to improve the quality of the pasturage;
2. To increase the fertility of pasture and hay lands by the use of readily available phosphates, nitrogen and manure;
3. The production of more leguminous roughage for feeding dairy stock;
4. The growing of silage crops and supplementary green crops, such as rape, peas and vetches;
5. That better methods of curing and handling of the hay and roughage crops be investigated;
Experimental Data (Cont'd).

(6) The control of the growth of Bracken and other prevalent weeds, by burning, cutting and thorough cultivation;

(7) The use of small pasture paddocks be instituted, providing frequent change of location, in order to encourage better quality of pasture plants;

(8) The feeding of balanced rations to the dairy stock, particular attention being given to the protein and mineral matter;

(9) The encouragement of mixed farming in preference to the present one line dairy farming;

CONCLUSIONS.

(1) The disease of Red Water is a localized one, only affecting cattle;

(2) The disease occurs on farms where the soils are comparatively low in fertility;

(3) The soils are of an acid nature, readily leached, with a tendency to be low in phosphates, nitrogen and organic matter;

(4) The hays and other roughage are generally low in available mineral elements;

(5) The herbage being significantly high in silica and aluminium, and possibly low in manganese;

(6) The probable causation of the disease is one of a nutritional origin, either from ingested irritant material or elaborated in the animal's system during metabolism;

(7) That further investigational work should be prosecuted in respect to the composition of the urines, bladders, flesh and milk of diseased animals.

SUMMARY.

(1) A complete statement of the history of this disease has been compiled;

(2) Its geographical distribution has been outlined;

(3) The local factors and conditions of occurrence of the disease have been fully discussed.
Summary (Cont'd).

(4) A discussion of the various recorded theories of causation is presented;

(5) An outline of the treatments found valuable in controlling the disease has been given, with a special reference to the Coral Rock Flour-Soda Binarbonate remedy.

(6) The characteristic symptoms, their possible and probable causes, have been fully discussed.

(7) A detailed analysis of soils, feeding stuffs, waters and other materials from Red Water and non-Red Water farms has been compiled and comparisons made between them.

(8) Suggestions have been made concerning further investigations.

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APPENDIX.

Comparative Analyses of Soils and Feeds.
Percent on Moisture Free Basis

Red Water Farms.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Sample</th>
<th>Silica (SiO₂)</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Iron (Fe₂O₃)</th>
<th>Aluminium (Al₂O₃)</th>
<th>Phosphates (P₂O₅)</th>
<th>Sulphates (S₂O₅)</th>
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<td>0.79</td>
<td>0.97</td>
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<td>8.65</td>
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### Comparative Analyses of Soils and Feeds - Red Water Farms

<table>
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<tr>
<th>Lab No.</th>
<th>Sample</th>
<th>Silica (SiO₂)</th>
<th>Calcium (CaO)</th>
<th>Magnesium (MgO)</th>
<th>Iron (Fe₂O₃)</th>
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## Appendix (Cont'd).

### Comparative Analyses of Soils and Feeds. - Red Water Farms.

<table>
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<th>Lab. No.</th>
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<th>Silica (SiO₂)</th>
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<th>Magnesium (MgO)</th>
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