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UNIVERSITY OF ALBERTA

COLLEGE OF AGRICULTURE

SOIL SURVEY
OF
MEDICINE HAT SHEET

BY

F. A. WYATT AND J. D. NEWTON

(With Appendix II by J. A. Allan)

University of Alberta

Edmonton, Alberta

Distributed by
Department of Extension, University of Alberta
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The soil survey report for the Medicine Hat Sheet is the result of co-operation between the Alberta Department of Agriculture, Dominion Department of the Interior, Topographical Branch, and the University of Alberta, Soils Department; together with Dr. J. A. Allan, Professor of Geology.

The Alberta Department of Agriculture has provided the funds for conducting the field work and the cost of printing the soil maps.

The Department of the Interior, Topographical Branch, has supplied the topographical data from the revision survey of this area and has been responsible for the drawing, lithographing and printing of the soil maps.

The members of the Soils Department of the University of Alberta have conducted the field and laboratory work in connection with mapping the soil types, collecting the samples, making the physical and chemical analyses and preparing the report. Dr. J. A. Allan has inspected the area covered by this report, and kindly prepared the chapter in the appendix dealing with the geology of the Medicine Hat Sheet.

(Published by the University of Alberta at the request of Hon. George Hoadley, Minister of Agriculture.)

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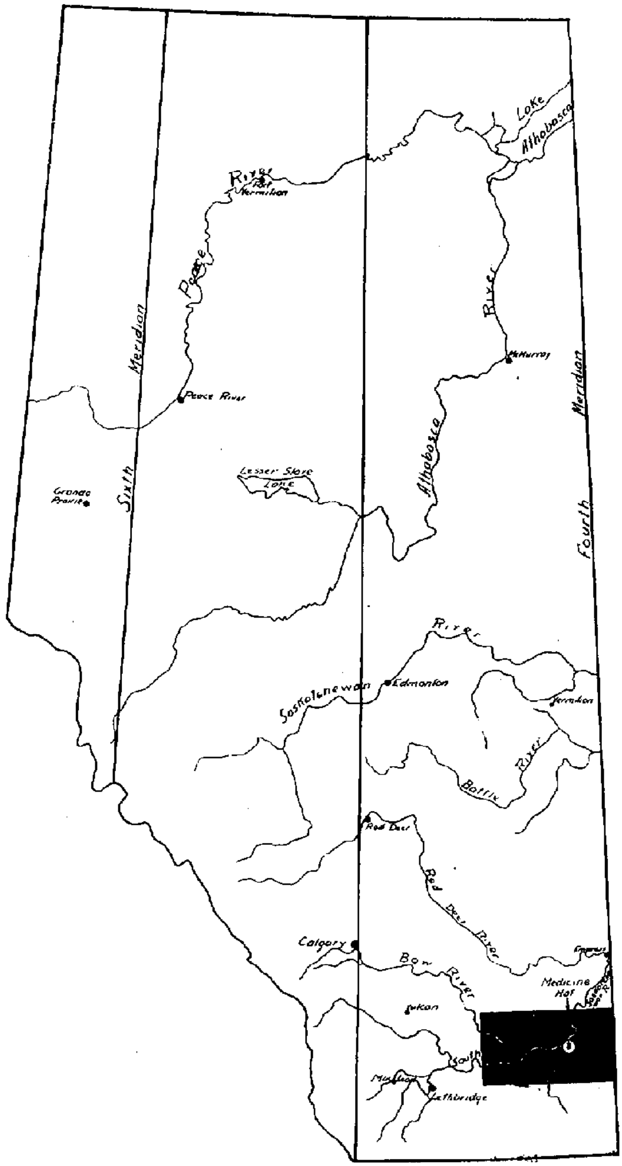

Fig. 1.—Sketch map of Alberta, showing location of Medicine Hat Sheet.

PREFACE

The farmer is among the first to recognize the fact that soils vary tremendously in their power to produce crops. This variation is due to differences in physical, chemical, and biological relationships within the various soil types. The report of the soil survey classifies the lands of the surveyed area according to these various characteristics and relationships, and discusses their effects upon crop production. The report is, therefore, valuable to the farmers, and likewise valuable to any other persons interested in the soils of the surveyed area, as, for example: land seekers, colonization agents, land appraisers, district agricultural representatives, experimental farm officials, bankers, road commissioners, real estate dealers, provincial and Dominion government officials.

The report accompanying the soil map describes the properties of the surface and subsoil of the various soil types, topography, drainage, crop adaptation, water supply, fertility invoice of the soils, systems of farming and methods of soil management, alkali and irrigation problems. It also contains a brief discussion of the climate and agricultural development of the area together with the important farm crops, transportation facilities and population.

The soil map is an important part of the report. It is made on the scale of three miles to the inch, and shows not only the different soil types represented by different colors, but also important physical features such as topography, roads, railroads, streams, towns, schools, and farm dwellings. Furthermore the soil map serves as a very convenient reference by which the better land can be distinguished from the poor land by any person interested in the soils of the surveyed area.

Our best land should be settled first, and since our soil resources are enormous it is unwise to allow farmers to settle on poor land until all the good land is taken up. It will mean greater prosperity for the province as a whole, as well as for the individual farmers, if only the better land is broken up at first. True, this particular argument does not apply to a large part of the area covered in this report, since much of the land was settled long before the survey was conducted. It would have been better to have conducted a survey of this kind before the land was brought under cultivation. Then certain of the lighter tracts, especially, might have been held for range land only, and not broken at all. It would have been a kindness to many of the then prospective settlers if this had been done, as many of these settlers have abandoned their farms after wasting a great deal of money, and years of their lives, in a vain attempt to produce wheat profitably in certain sections of the Medicine Hat Sheet.

There has been some agitation in the past to have the government help move settlers from the dryest sections to the moister districts. In cases of this kind the soil maps should prove very useful, in conjunction with other data, since the maps would show which soil areas in a given district would be likely to suffer most severely from drought, and hence would show which farmers should be helped.

It is true that in many cases rainfall is the main limiting factor in crop production, but, in a given district, with a given rainfall, different soil types differ greatly in their crop-producing power, or ability to resist drought. The sand and sandy loam soils, for example, are not nearly as drought resistant as the loam and silt loam soils.

The results of crop, fertilizer and cultural method experiments obtained at the larger government experiment stations in our province do not necessarily apply to all parts of the province. The men in charge of the experiments recognize that it is very often necessary to determine whether the results obtained at the stations do or do not apply to the various local districts. When planning extension experiments in various parts of the province the soil maps should prove very valuable, since they would show where the plots should be placed in order to represent important or extensive soil areas. The farmers round about would then know whether a certain crop or treatment could be expected to bring them results similar to those obtained on the experimental plots, since the soil maps would tell them whether the soils were, or were not, alike.

Similarly, the soil report tends to place the information of one farmer at the disposal of other farmers. If one farmer sees that another farmer on land classified the same as his, is making more money, he can observe what crops the more successful farmer is growing, and how he is working his land, and, by adopting similar crops and methods he may expect to obtain similar results.

If it is worth while to conduct surveys to determine our mineral, timber and various other resources, and to map out in detail the topographical features of the province, surely it is worth while to take an inventory of our most important natural resource, namely, the soil. Soil surveys are of the greatest economic importance and furnish information that can be secured in no other way.

Soil Survey of Medicine Hat Sheet, Alberta

BY

F. A. WYATT AND J. D. NEWTON*

(With Appendix II by J. A. Allan)

DESCRIPTION OF THE AREA

The Medicine Hat Sheet is located in south eastern Alberta, as indicated by the sketch map. It consists of an area 90 miles east and west by 48 miles north and south, and its southern boundary line is 48 miles north of the international boundary. More exactly, it consists of that portion of townships 9 to 16 (inclusive) which occupies ranges 1 to 15 (inclusive), west of the 4th meridian.

The eastern boundary of the surveyed area is formed by the Saskatchewan boundary, and extends from the Cypress Hills, in the south, to the northern boundary, just north of Schuler; the northern boundary, extends from the Saskatchewan boundary just north of Schuler, west to Lake Newell and Bow Slope; the western boundary lies just east of Vauxhall and Taber, and extends south from Bow Slope to a point just south-east of Taber; and the southern boundary extends east from this point south-east of Taber to the northern slope of the Cypress Hills, at the Saskatchewan boundary; Medicine Hat lies in the east-central part of the Sheet.

The soil map for the area above described represents 120 townships, or 2,764,800 acres.

The area covered by this report lies wholly within the treeless or bald prairie portion of southern Alberta.

The surface of the Medicine Hat Sheet is, in greater part, undulating or gently rolling. There are, however, some very considerable areas of rolling, and even hilly land, especially in the eastern half of the Sheet. The extent of these rolling and hilly areas is shown by the hatching on the map, and is discussed later in connection with the description of the various soil types. (See Plates 1 and 2.)

The general elevation of the Medicine Hat Sheet is about 2,400 to 2,800 feet. One might expect a decrease in elevation as the distance from the Rockies increases, but it cannot be said that the general elevation at the eastern end of the Sheet

*Messrs. J. L. Doughty, A. S. Ward and T. H. Mather assisted with the field, analytical and mapping work during the course of the preparation of this report.

is lower than at the western end. In fact, the greatest elevation by far is to be found in the south-east corner of the Sheet, where the northern edge of the Cypress Hills is included within the surveyed area. Here the elevation of the original plain is over 4,000 feet, or nearly as great as the elevation of the town of Banff, Alberta.

The slope is generally towards the rivers which flow through the surveyed area, namely, the South Saskatchewan river and its tributaries. In the south-east corner there is a pronounced slope northward towards the river at Medicine Hat, and towards the large clay flat extending east and west, which is followed by the main line of the Canadian Pacific Railway east of Medicine Hat. In the north-east quarter of the Sheet there is a good deal of hilly and rolling land, but there is no general slope in any one direction.

The Medicine Hat Sheet is drained by the South Saskatchewan river and its tributaries. The Bow and Oldman rivers enter the western end of the Sheet, and, at a distance of about 16 miles east of the point of entry they meet to form the South Saskatchewan river, which flows in a generally easterly direction through the center of the Sheet, as far as the town of Medicine Hat, or to a point about 30 miles west of the Saskatchewan boundary. At Medicine Hat the river turns sharply north, and leaves the Sheet at a point about 25 miles west of the Saskatchewan boundary.

A number of drainage creeks, tributary to the main rivers, carry water only at certain seasons of the year. One of the most important of these is Twelve Mile Coulee, in the north-west corner of the Sheet, which drains south and empties into the Bow river. Then there is a series of creeks, in the south-east quarter of the Sheet, running north from the Cypress Hills elevation, and then turning towards Medicine Hat, where they empty into the South Saskatchewan river. The most important of these, from east to west, are: Mackay, McAlpine, Ross, Gross Ventre, Bullshead, and Seven Persons. Other drainage ways which should be mentioned are Forty Mile Coulee, in the south-west quarter of the Sheet, and Bull Springs Coulee, which drains Red Deer Lake, in the north-east quarter.

The southern end of Lake Newell lies within the surveyed area; this lake is really a large C.P.R. irrigation reservoir, which occupies a depression at the north-west corner of the Sheet. A number of other important depressions, lakes, and flats occur elsewhere, particularly in the rolling and hilly areas of the north-east corner of the Sheet. The more important of these are Red Deer Lake, Chappice Lake, and the large lake or flat known as Many Island Lake. There are many other small lakes and sloughs in this corner of the Sheet, and in the south-east corner, near the base of the Cypress Hills. Elsewhere the lakes and sloughs are less plentiful, but are to be found here and there in various parts of the Sheet.

Lake Newell, of course, is a fresh water lake, containing stored-up water from the Bow River. The other lakes and sloughs referred to are all more or less "alkali", because they lack outlets for the most part, and salts naturally tend to leach into these depressions. Many of these lakes and sloughs dry up during the summer months of the drier years, but contain water at all seasons during the years of heavier rainfall. Apart from these scattered lakes and sloughs, the country is naturally well drained.

The soil material consists mainly of glacial drift. It is doubtful if much glacial material from the Rockies was carried as far east as the Medicine Hat Sheet. Considerable material has been carried by the glaciers from north central Canada, or from the region just west of Hudson Bay, although most of the drift no doubt consists of material weathered from the underlying sandstones and shales, and moved about to some extent by glaciers and glacial streams.

Within the boundaries of the Medicine Hat Sheet are included some of the dryest districts of Alberta, and some areas of soil drifting. Some important irrigation districts are, in part, located within this Sheet. These conditions will be discussed in later sections of the report.

The main towns or centers of population occur along the railroads. Medicine Hat, with a population of about 9,000 is much the largest center, and Redcliff, just a few miles west of Medicine Hat, is the second largest town. Other towns along the main line of the C.P.R. west of Medicine Hat, are Suffield and Alderson. East of Medicine Hat, the more important towns along the main line are Dunmore, Irvine, and Walsh. Along the Crowsnest line, from Medicine Hat west, the principal towns are Seven Persons, Winnifred, Bow Island, Burdett, Grassy Lake and Purple Springs. Schuler, in the north-east corner of the Sheet, is the present terminus of a new C.P.R. branch line which enters the Sheet at its north-east corner. Taber and Vauxhall are located just outside the Sheet at its western end, the former on the Crowsnest line, and the latter on the Suffield-Lomond branch line.

The transportation facilities for a large part of the Sheet are good, and, for the whole area the transportation facilities are probably quite as good as the average for other districts of similar size in the southern half of Alberta. The C.P.R. system is the only one traversing the area. The main line crosses the surveyed area from its eastern end, in a north-westerly direction, to a point on the northern border, near the western end of the area. The Crowsnest line from Lethbridge enters the western end of the Sheet, at a point a few miles north of the southern boundary of the surveyed area, and extends east across the area to where it joins the main line just east of Medicine Hat. The Suffield Lomond branch line leaves the main line at Suffield, in the north central part of the surveyed area, and extends south-west to Ronolane, where it crosses the Bow River, and then continues on west to where it leaves the western boundary of the Sheet, at a point about halfway between the northern and southern boundaries. Another branch line enters the Sheet at its north-east corner, and, for the present, terminates at Schuler, in the north-east corner of the area. Most of the farmers are located within easy reach of railroads, although, in some cases, it is necessary for farmers to haul their grain a distance of twenty miles or more.

For the most part the district is well traversed by public highways, of which the main ones are well-graded dirt roads. These roads are good during the greater part of the year.

CLIMATE

The climate of the Medicine Hat Sheet is typical of the climate of the high plains region of Western Canada. It is characterized by long, bright, moderately warm summer weather, and bright, cold, dry, winter weather. There are occasional high winds on this treeless plain, and the area is in the path of the "Chinooks", or warm south-west winds from the Pacific, which bring about occasional thaws during the winter. The climate is characterized by a high proportional amount of sunshine (2,354 hours per year as an average of 14 years).

Meteorological records show that evaporation from a free water surface is greater on the treeless plains of Alberta than in the park belt. This is in all probability due chiefly to the higher and more frequent winds of the plains. For example, the figures for May, June, July, August and September, 1919, show evaporation from a free water surface to be 28.11 inches at Claresholm, as against 19.25 inches at Olds. The evaporation at both places was greatest during July. These records indicate that losses of water by evaporation from a moist soil of the treeless plain would be greater than from a similarly moist soil of the park belt.

Table I, compiled from the Dominion Meteorological Records, shows the average seasonal distribution of precipitation for a period of thirty years at Medicine Hat. This distribution is representative of the Medicine Hat Sheet. For the annual distribution see Table II.

TABLE I.—SEASONAL DISTRIBUTION AT MEDICINE HAT.
PRECIPITATION IN INCHES—YEARS 1885-1914

	PRECIPITATION			SNOW		
	Average Monthly Fall	Greatest Amount in 1 Month	Total Am't in driest year, 1886	Total Am't in wettest year 1899	Average Monthly Fall	Greatest Amount in 1 Month
December	0.53	1.42	0.28	0.91	4.7	12.0
January	0.61	1.72	0.00	1.12	6.1	16.8
February	0.61	1.51	0.00	1.13	6.0	15.1
Winter—	1.75		0.28	3.16	16.8	
March	0.61	1.62	0.32	1.17	5.0	16.2
April	0.61	2.26	0.80	0.87	2.4	12.9
May	1.75	6.29	1.41	3.32	.5	8.0
Spring......	2.97		2.53	5.36	7.9	
June	2.57	5.62	1.53	2.60	T	1.2
July	1.73	4.86	0.78	3.79	....	....
August	1.51	5.65	0.11	7.60	....	....
Summer....	5.81		2.42	10.99	T	
September ...	0.92	2.41	0.19	1.66	0.4	4.0
October	0.62	3.48	0.79	0.80	1.1	21.0
November ...	0.72	3.11	0.51	0.31	6.4	31.1
Fall........	2.26		1.49	2.77	7.9	
Year......	12.79		6.72	22.28	32.6	

From Table I it may be seen that about 45 per cent. of the average annual precipitation at Medicine Hat for the 30-year-period, 1885-1914, fell during the summer months; that the growing season, May, June, July and August, received almost 60 per cent. of the yearly rainfall, and that approximately 76 per cent. fell during the months of April to October inclusive. With such a favourable distribution the rainfall is decidedly more effective in producing crops than a similar annual precipitation would be, provided it were more largely distributed over the winter and early spring seasons. At best, of course, the average annual precipitation is rather small.

It may be noted that there occur great differences in the annual rainfall, as that of the driest season is less than one-third that of the wettest season. This fact may be further perceived by referring to Table II. There is probably as much proportional variation in the distribution of the snowfall as of rainfall, and the soils of the Sheet are often left bare for long periods during the winter months, which permits them to dry out to some extent, and occasionally blow. Soil drifting, however, is by no means as great a problem as in the Macleod Sheet to the west.

Rainfall records have been kept at Medicine Hat since 1885. In Table II, however, only the records for the 21-year period, 1904-1924, are given, thus making it possible to give the records for the same years at Lethbridge and Edmonton, for the purposes of comparison.

TABLE II.—PRECIPITATION RECORDS FOR MEDICINE HAT, LETHBRIDGE AND EDMONTON, 1904-1924.

Year	Rainfall in Inches		
	Medicine Hat	Lethbridge	Edmonton
1904	9.70	11.30	19.87
1905	8.99	13.78	15.56
1906	12.62	22.48	19.35
1907	6.86	15.50	16.62
1908	10.22	16.37	12.50
1909	9.78	11.69	12.94
1910	7.55	7.97	14.93
1911	16.24	21.28	20.67
1912	10.38	13.21	20.18
1913	13.62	14.17	19.54
1914	12.17	17.58	25.29
1915	16.13	17.40	18.64
1916	17.90	25.92	20.95
1917	11.13	18.87	15.25
1918	10.19	8.94	17.86
1919	7.66	13.36	16.43
1920	10.74	14.05	18.16
1921	11.74	12.13	15.22
1922	11.34	13.22	13.73
1923	13.64	16.40	16.91
1924	9.86	16.00	18.76
Average	11.35	15.03	17.59

From Table II it may be noted that for the three points mentioned, during the wettest year there was, approximately, from two to four times as much rainfall as during the driest year. During seven of the twenty-one years, 1904 to 1924, the annual rainfall at Medicine Hat dropped below 10 inches, and in two of the years at Lethbridge the annual rainfall was less than 10 inches. At Edmonton, however, the lowest record for this period was 12.5 inches. The average annual precipitation was lower at Medicine Hat than at either of the other two points referred to. It should be noted, however, that the precipitation records at Medicine Hat are not quite representative of the entire Sheet. For example, the rainfall near the Cypress Hills, in the south-east corner of the Sheet, is usually somewhat greater than at Medicine Hat.

When the annual precipitation is below a certain minimum it is almost impossible to produce a crop for that year, and what little rainfall does come has a very low efficiency factor. This is discussed in connection with the topic of agriculture.

The frost-free periods have a considerable bearing upon the risk in producing certain of the farm crops, and usually we may expect the time taken to mature the crop to be longest during the wettest years; thus the danger from frost would be increased for the wettest years.

The average length of the frost-free period for the twenty-three years from 1902 to 1924 was 127 days at Medicine Hat, 109 days at Lethbridge, and 90 days at Edmonton.

The shortest frost-free period in any one year, at any one of the three places was 52 days; this short period occurred at Edmonton in 1918. The shortest frost-free period at Lethbridge was 70 days (1902) and at Medicine Hat 98 days (1917). The longest fost-free period at Edmonton was 118 days, at Lethbridge 142 days, and at Medicine Hat 148 days. In only one year out of the twenty-three was the frost free period less than 100 days at Medicine Hat, and in only seven years at Lethbridge, but at Edmonton the frost-free period was less than 100 days in seventeen out of the twenty-three years.

It should be noted, also, that the frost free period is not usually as long as the growing season for wheat and many other crops. As a rule the earliest fall frosts are too light to damage the ripening wheat, and the late spring frosts seldom affect the wheat crop seriously.

As previously stated, the climate of the plains area is characterized by moderately warm summer weather, and cold, dry winter weather, with a high proportional amount of sunshine, and occasional high winds. An idea of the variations in temperature may be obtained from Table III taken from the Dominion Meteorological Records for the ten-year period, 1905-1914. In order to make clear the various column headings in Table III let us consider the December figures in the uppermost line.

The first column, first line, simply states the average or mean temperature for December throughout the ten-year period.

In the second column, first line, is given the mean or average maximum temperature for December. This is obtained as follows: an average of the highest daily temperatures of each of the ten December is taken and 30.8 represents an average of these ten figures thus obtained. The mean minimum temperature for December is calculated similarly for column three.

In the fourth column, first line, is given the highest monthly mean, which in this case represents the average temperature of the warmest December during the ten-year period. Similarly, the figure in the fifth column represents the averag temperature of the coldest December that occurred during the ten-year period.

In the sixth column, first line, is given the highest or warmest December temperature that occurred in the ten-year period, and in the seventh the lowest, or coldest.

TABLE III.—MONTHLY, SEASONAL AND ANNUAL MEANS AND EXTREMES AT MEDICINE HAT, ALBERTA, 1905-1914.

Month	TEMPERATURE						
	Mean	Mean Maximum	Mean Minimum	Highest Monthly Mean	Lowest Monthly Mean	Extreme Highest	Extreme Lowest
December	21.1	30.8	11.4	29.4	15.0	64	—32
January	11.3	21.5	1.0	26.3	—8.1	56	—41
February	16.5	27.0	6.0	25.8	9.6	64	—44
Winter	16.3	26.4	6.1			64	—44
March	30.5	42.9	18.1	45.0	17.5	84	—22
April	46.1	60.1	32.2	54.7	36.8	96	— 3
May	54.6	67.4	41.7	58.2	48.5	99	15
Spring	43.7	56.8	30.7			99	—22
June	64.1	77.1	51.1	68.6	59.2	102	30
July	69.2	83.4	55.0	75.6	65.1	104	38
August	66.3	80.8	51.8	69.6	62.0	103	31
Summer	66.5	80.4	52.6			104	30
September	58.1	71.5	44.6	63.1	51.5	92	20
October	46.2	57.8	34.7	51.8	42.4	85	2
November	32.5	42.4	22.6	38.5	20.7	69	—26
Fall	45.6	57.2	34.0			92	—26
Year	43.0	55.2	30.8			104	—44

The yearly mean or average temperature is 43 degrees Fahrenheit. The mean maximum yearly temperature is about 55 degrees. This figure represents an average of the highest daily temperatures throughout the year, for the ten-year period under consideration. Similarly, the mean minimum yearly temperature, which is about 39 degrees, represents an average of the lowest daily temperatures throughout the year, for the ten-year period under consideration.

The highest temperature recorded is 104 degrees, and the lowest 44 degrees below zero. However, these extremes do not give a correct idea of the usual variations in temperature. A better idea of ordinary temperature variations is given by a consideration of mean maximum and mean minimum temperatures. The mean maximum for winter is about 26 degrees, and the mean minimum about 6 degrees; in other words. the average highest temperature for winter is several degrees below freezing, and the average lowest is about 6 degrees above zero. The mean temperatures for spring and fall are about equal to one another, although it will be observed that the fall is a bit the warmer.

The mean temperature for summer is about 66 degrees, the average maximum being about 80 degrees, and the average minimum about 53 degrees. During this season the mercury seldom reaches the 100 mark, and very rarely goes down to the freezing point. In general, the summer has long, warm days of bright sunshine which permits of very rapid growth of crops. The nights are cool.

AGRICULTURE

The big rush of homesteaders, with its consequent development of the grain farming industry, began in 1909, and continued during 1910 and 1911. Previously the agriculture of the Medicine Hat district consisted almost wholly of ranching, which had been developed after the coming of the C.P.R. in 1883.

Most of the farmers throughout the area, other than the few on irrigated farms, keep little live stock, and practice mixed farming to but a very limited extent. As a rule they still depend on the wheat crop as the chief source of income.

A large proportion of the area is uncultivated, and ranching is still practised in various places. It is altogether likely that much of the unoccupied land, of which a good deal was homesteaded and then deserted, will again be used for ranching in the near future.

The combined area of irrigation schemes in the Medicine Hat Sheet is small as compared to the total area of the Sheet, but the part which irrigated land will play in agricultural production, under intensive methods of farming, will undoubtedly be altogether out of proportion to its extent. It may be many years, however, before irrigation water is actually applied to much of the land of the irrigation schemes within the Sheet. (For a detailed discussion of the importance and extent of irrigation schemes in the Medicine Hat Sheet, see page 00.) Wherever the land is irrigated, soil drifting is effectively prevented. This point is worthy of mention here, as soil drifting, though much less serious than in the Macleod Sheet to the west, is nevertheless a rather serious problem. (For a detailed discussion of soil drifting in the Medicine Hat Sheet, see page 46.)

The number of cultivated acres in the Medicine Hat Sheet can be computed only very roughly. If we estimate the untilled areas on our township maps, surveyed in 1922 and 1924, and add to this area the eroded, river bottom, and water areas, there is left about one-half million acres. This means that less than one-fifth of the total area of the Sheet is now being cultivated.

TABLE IV.—ACREAGE OF VARIOUS CROPS PRODUCED IN MEDICINE HAT SHEET (1915-1920).

Year	CROPS					
	Wheat	Oats	Barley	Rye	Flax	Total
1915:						
Acres	139,742	49,474	7,178	594	14,513	211,501
% Total Crops	66.07	23.39	3.39	0.28	6.86	....
1916:						
Acres	128,033	41,981	5,926	569	13,742	190,251
% Total Crops	67.29	22.06	3.12	0.29	7.22	....
1917:						
Acres	166,283	537,264	10,845	3,996	39,087	757,475
% Total Crops	21.95	70.93	1.43	0.52	5.16	....
1918:						
Acres	145,721	37,179	2,204	5,485	22,321	212,910
% Total Crops	68.42	17.46	1.03	2.58	10.48	....
1919:						
Acres	234,384	23,063	1,294	1,881	9,683	270,305
% Total Crops	86.71	8.53	0.48	0.69	3.58	....
1920:						
Acres	437,141	33,747	1,345	2,352	21,862	496,447
% Total Crops	88.05	6.80	0.27	0.48	4.40	....

The data in Table IV, showing the acreage of various crops produced in the Medicine Hat Sheet, are obtained from the Provincial Annual Reports of Agriculture, and are the figures given for the constituencies of Medicine Hat and Redcliff. Parts of these constituencies lie outside the Medicine Hat Sheet, but it is thought that the crop acreages outside the Sheet are roughly equivalent to the crop acreages within the Sheet of two other constituencies, Taber and Bow Valley, which lie partly within the Sheet. It will, therefore, be understood that the figures given in this Table are simply estimations of the crop acreage of the Medicine Hat Sheet.

While Table IV includes figures for only six years, it is sufficient to show the general distribution of the various agricultural crops of the Medicine Hat Sheet, and it will be observed that the wheat and oat crops nearly always make up over 90 per cent. of the total crop area, and that wheat is usually grown to a much greater extent than oats. There is a small proportion of the total crop area devoted to corn, alfalfa, cultivated grasses, and other crops, not mentioned in Table IV, but exact figures for these crops are not available, and they are, therefore, omitted from the table.

TABLE V.—COMPARATIVE YIELDS OF CROPS IN ALBERTA.
BUSHELS PER ACRE—13-YEAR AVERAGE, 1910-1922

Constituency	Spring Wheat	Winter Wheat	Oats	Barley	Rye	Flax
Medicine Hat	12.73	16.72	24.85	17.57	14.10	5.68
Redcliff	12.62	17.74	23.50	16.22	15.37	6.54
Average	12.67	17.23	24.17	16.89	14.73	6.11
Claresholm	19.24	20.57	31.11	21.10	18.69	10.57
South Edmonton ..	23.76	22.53	36.46	28.60	17.76	11.58
Aver. for Province	19.52	19.30	31.71	22.81	18.17	8.87

Figures for the comparative yields in bushels per acre obtained in the principal constituencies of the Medicine Hat Sheet (Table V) were taken from the Annual Report of the Department of Agriculture of the Province of Alberta for the year 1922. Yields are given for the constituencies of Medicine Hat and Redcliffe, and the average yields of these two constituencies are given also, as these should represent the averages for the entire Medicine Hat Sheet. Yields for the constituencies of Claresholm and South Edmonton, and for the province as a whole, are also included in this table, in order to compare the yields of the Medicine Hat Sheet with the yields of the moister sections to the west and to the north, and with the average yield of the whole province. It will be observed that the yields obtained in the Medicine Hat area are distinctly lower than obtained in districts at some distance to the west and to the north and lower than the average yields for the whole province. For example, the average yield of spring wheat, the principal crop of the two Medicine Hat constituencies, is 12.67 bushels, whereas the average for the whole province is 19.52 bushels.

The yields in Table V are obtained from threshers' returns, and are the most reliable estimates we have, yet they do not tell the entire story. The threshers' returns include the bushels actually threshed and the statement as to the acres thus represented; but, in the first place, the exact acreage is not always known, and, in the second place, a considerable portion of the crop seeded may never be threshed in the poorer seasons. Therefore, the returns are very good estimates for the better crop years, but are somewhat too optimistic for the poorer years.

The amount and distribution of annual rainfall are two of the most important factors in the production of crops in the Medicine Hat Sheet. In order to show the relationship of wheat yields, total precipitation, and precipitation during the wheat growing months, Table VI, has been constructed. This table was prepared by taking separately the total annual precipitation as given in Table II, the rainfall for the four months, April, May, June, July, and the annual yields of wheat, for the two constituencies, Medicine Hat and Lethbridge. It is quite evident that a large proportion of the total precipitation occurs during the growing season, and that the yield fluctuations are directly related to the rainfall fluctuations.

The average yields of wheat for these constituencies are 13.43 and 17.28 bushels respectively for Medicine Hat and Lethbridge, while the average annual rainfalls are 11.32 and 14.85 inches respectively. The extreme variation in yields is from less than 3 to more than 43 bushels, whereas the extreme variation in annual rainfall is from a little less than 7 to about 26 inches.

TABLE VI.—YIELDS, SEASONAL AND ANNUAL PRECIPITATIONS, 1904-1922.

Year	MEDICINE HAT CONSTITUENCY			LETHBRIDGE CONSTITUENCY		
	Yield per acre, wheat, bushels	Precipitation, April, May, June, July.	Annual Precipitation.	Yield, per acre, wheat, bushels.	Precipitation. April, May, June, July.	Annual Precipitation.
1904	....	4.86	9.70	....	6.03	11.30
1905	15.87	6.21	8.99	9.43	6.01	13.78
1906	18.66	11.83	12.62	21.79	13.04	22.48
1907	11.36	3.66	6.88	21.34	7.34	15.50
1908	7.68	6.55	10.22	20.69	11.50	16.37
1909	22.80	6.84	9.78	19.75	8.38	11.69
1910	7.02	2.61	7.55	6.77	1.69	7.97
1911	18.23	8.38	16.44	20.70	9.70	21.28
1912	15.58	4.74	10.38	16.71	5.37	13.21
1913	11.11	7.10	13.62	18.57	8.21	14.17
1914	3.21	2.89	12.17	6.31	4.24	17.58
1915	37.48	10.97	16.13	43.61	11.35	17.40
1916	23.33	10.70	17.90	34.69	11.10	25.92
1917	20.00	3.31	11.13		5.31	11.87
1918	2.99	3.52	10.19	7.05	2.31	8.94
1919	2.36	3.74	7.66	5.15	3.84	13.36
1920	7.73	5.46	10.74	13.02	9.02	14.05
1921	7.16	6.71	11.74	9.77	6.42	12.13
1922	9.25	6.51	11.34	18.50	7.63	13.22
Average	13.43	6.13	11.32	17.28	7.82	14.85

The lowest yield does not always occur during the season of lowest rainfall, neither does the highest yield always occur during the season of greatest rainfall, otherwise 1916 should have shown the highest yield. Other factors, such as a succession of either wet or dry years, distribution of rainfall, severe frosts, crop diseases, etc., prevent absolute harmony between rainfall and yields.

However, in general, the seasons of low rainfall are the seasons of low yields, and likewise the seasons of high rainfall are the seasons of high crop yields. A better idea of the relationship between rainfall and yield than is obtained from Table VI may be obtained from Figure 2.

The yields of wheat and the annual rainfall records for Figure 2 are taken from Table VI. There is a bit closer correlation between the yield curves and the rainfall curves of the growing period months of April, May, June, and July than there is between the yield curves and the annual rainfall curves as a rule.

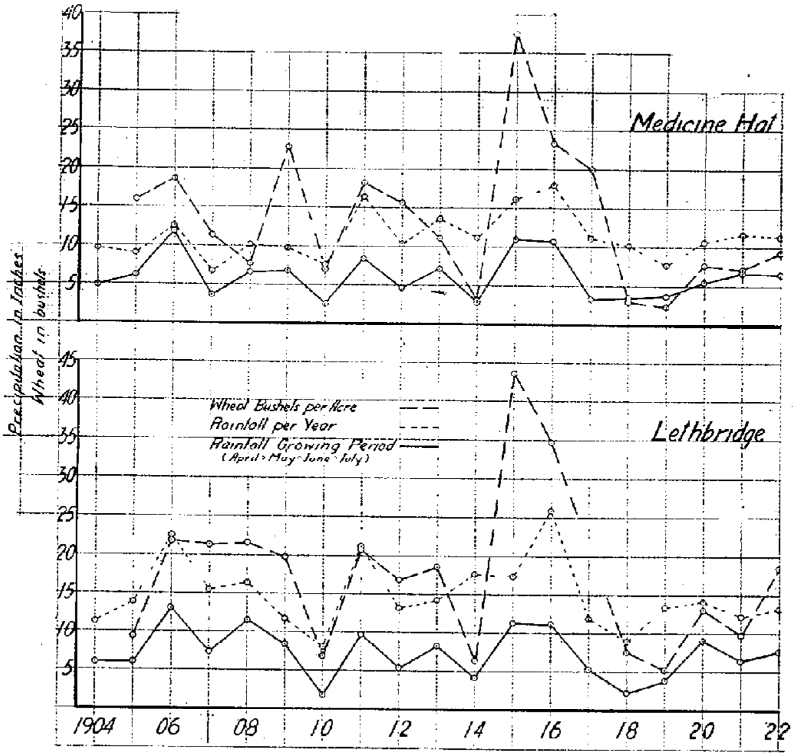

Fig. 2.—Yields of wheat, seasonal and annual precipitation.

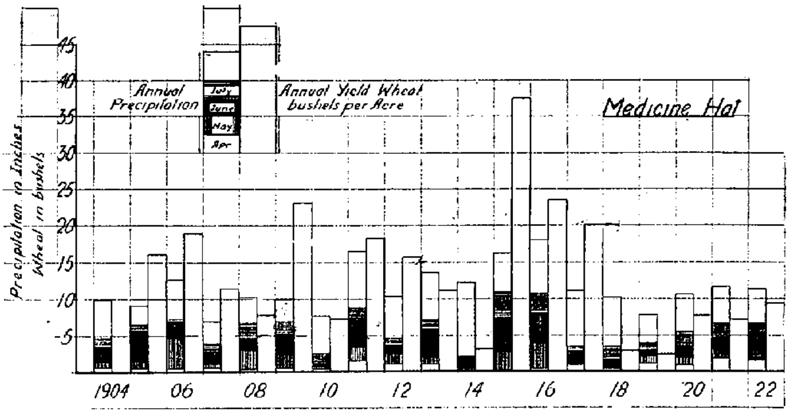

Fig. 3.—Yields of wheat at Medicine Hat, monthly and annual precipitation.

A still more detailed comparison between crop yields and rainfall may be made. Such a comparison for the Medicine Hat Constituency only is shown in Figure 3. This figure shows graphically the relationship between wheat yield on the one hand, and, on the other hand, the precipitation of the growing months, April, May, June and July, and the annual precipitation for the years 1904 to 1922.

As previously pointed out, the economic efficiency of a unit of rainfall is generally comparatively low during the drier seasons, since the rainfall during such seasons is sufficiently low to materially reduce, or even almost inhibit, the maturing of crops. By dividing the yield figures by the rainfall figures for the croresponding year we obtain figures representing the bushels of wheat produced for each inch of rainfall. Such values for the 18 years are reported in Table VII.

The average number of bushels of wheat produced by each inch of rainfall is virtually the same at both points; in fact, the agreement is remarkably close. However, there is a great amount of variation from season to season; the drier years produced only about 0.3 to 0.5 bushels per inch of annual rainfall, whereas the wetter seasons produced as much as 2.5 bushels for a similar unit of rainfall. There are some exceptions to the rule that during years of extremely low rainfall the efficiency of a unit of water is much less than during the seasons of average or high rainfall, but these exceptions may usually be explained by observing the previous year's precipitation, and the precipitation of the growing season. For example, the yields per inch of rainfall in 1914 were lower, considering the total annual precipitation, than one would have expected, but it will be observed that the precipitation of the growing season months was exceptionally small.

TABLE VII.—WHEAT BUSHELS PER ACRE INCH OF RAINFALL

Year	MEDICINE HAT CONSTITUENCY			LETHBRIDGE CONSTITUENCY		
	Annual rainfall	Rainfall April. May, June, July	Bu. per inch of annual rainfall	Annual rainfall	Rainfall, April, May, June, July	Bu. per inch of annual rainfall
1905	8.99	6.21	1.76	13.78	6.01	.68
1906	12.62	11.83	1.48	22.48	13.04	.97
1907	6.88	3.66	1.65	15.50	7.34	1.38
1908	10.22	6.55	.75	16.37	11.50	1.27
1909	9.78	6.84	2.33	11.69	8.38	1.69
1910	7.55	2.61	.93	7.97	1.69	.86
1911	16.24	8.38	1.12	21.28	9.70	.97
1912	10.38	4.74	1.50	13.21	5.37	1.26
1913	13.62	7.10	.81	14.17	8.21	1.31
1914	12.17	2.89	.26	17.58	4.24	.36
1915	16.13	10.97	2.32	17.40	11.35	2.51
1916	17.90	10.70	1.30	25.92	11.10	1.30
1917	11.13	3.31	1.80	11.87	5.31	
1918	10.19	3.52	.29	8.94	2.31	.79
1919	7.66	3.74	.31	13.36	3.84	.39
1920	10.74	5.46	.72	14.05	9.02	.92
1921	11.74	6.71	.61	12.13	6.42	.80
1922	11.34	6.51	.81	13.22	7.63	1.40
Average	11.40		1.15	15.05		1.11

POUNDS OF WATER REQUIRED TO PRODUCE ONE POUND OF DRY MATTER.

	MEDCINE HAT	LETHBRIDGE
Grain and Straw	1642	1701
Grain only	3284	3402

It is shown, in Table VII, that each inch of annual rainfall produced as an average of 18 years, from 1.11 to 1.15 bushels of wheat per acre. From this it may be calculated that each pound of wheat (grain only) required about 3,366 pounds of water. Now, if we assume that the yield of straw per acre is equal to the yield of grain we have an average water requirement of 1,684 pounds for each pound of dry matter produced in the form of the wheat crop.

The figures in Table VII represent the actual conditions as they exist in the Medicine Hat and Lethbridge constituencies, according to the present system and methods of farming. The relationship of crop yields to the evapo-transpiration and run-off water, or to the sum of the quantities of water removed from the soil by evaporation, transpiration through plants, and run-off, is clearly shown. The water requirement is undoubtedly too high, and the farmer, by paying more attention to crop rotation, fallowing, and other cultural practices, should be able to materially reduce it. For example, the introduction of summer fallow substitutes, such as corn, would almost certainly lead to a more efficient utilization of available moisture.

On account of a series of dry years much of the land that had been homesteaded and broken for wheat farming was, a few years later, deserted, and this land has become very weedy, Russian thistle being especially abundant. Gradually, however, these weeds are being displaced by native grasses, and eventually a good grass sod will be formed, and the land will once more be valuable as pasture or ranch land. No doubt this process could be hastened in many places by sowing suitable grass seed.

Even yet settlers are moving away from the district, and it is evident that the unmodified wheat farming practice cannot be depended upon as a permanent system of agriculture. Where suitable water supplies are available from wells or rivers, some live stock should be kept and some forage or green feed crops should be grown in addition to the wheat crop. Among the forage crops which might be suggested are rye, oats, corn, brome grass and sweet clover. It is possible to produce green feed for live stock in dry years when the wheat crop is not satisfactory. Cattle and sheep should be kept in greater numbers, and some of the land could then be left in pasture at all times. For much of the better districts of the Medicine Hat Sheet it is considered that this is probably the best solution of the farming problem.

For much of the rougher land, however, and for some of the larger sand areas, the only solution would seem to be to turn the land back to ranching. Here again, of course, an adequate water supply is essential. It has been suggested that the ranchers might obtain winter feed for their live stock from the irrigation districts at the western end of the Sheet. Ranching was carried on in the Medicine Hat district long before active homesteading commenced, and it is still practiced to a limited extent. Increases in cattle and sheep ranching are, however, to be expected.

SOILS OF THE MEDICINE HAT SHEET

The soils of the Medicine Hat Sheet (see accompanying map) consist chiefly of glacial drift derived largely from the material weathered from the underlying formations. Some of the drift material, however, was undoubtedly carried long distances by the Keewatin glaciers which moved down from the Hudson's Bay region. The formations underlying this glacial drift material were laid down during the upper Cretaceous Period. (For detailed statement of the geology of this area, see Appendix II, by Dr. J. A. Allan.) The Medicine Hat Sheet is almost wholly underlaid by the Belly River formation. Around the Cypress Hills in the south-east corner of Sheet the glacial drift is underlaid by the Bearpaw formation. Then there is a narrow ring of Edmonton formation close to the hills, and the Cypress hills proper consist of unglaciated Later Tertiary formations. This Later Tertiary material is really just south of the Medicine Hat Sheet boundary. The glacial drift and boulder clay overlying the various formations varies in thickness from a few inches to more than one hundred feet. In a few locations there is no covering of drift, and the country rock may be seen at the surface, weathering in place. The underlying formations consist mainly of sandstone and shale or clay, each of which forms a somewhat different soil on erosion.

The general effect of glaciation has been to level up the lowest areas and leave a wide plain. This plain is by no means uniformly level, however, as it varies considerably in elevation, and it is cut up by many drainage channels, consisting of coulees, creeks and rivers. A good deal of the plain is rolling in nature, and in some parts it is quite hilly. A very large proportion of the land of the eastern third of the Medicine Hat Sheet is of a rolling or hilly nature (see map).

These hills have an elevation, in general, from 200 to 300 feet above the adjacent country. With the exception of the Cypress Hills in the south-east corner, the rolling and hilly land was largely formed by glacial deposits. The main hilly areas occur around the Cypress Hills in the south-east corner, along the northern edge of the eastern half of the Sheet, and around Many Island Lake, at the eastern end of the Sheet.

Much of the glacial material remains in nearly the same position as when deposited by the melting ice sheet. There is evidence of only a moderate amount of reworking of the materials. Many of the hilly areas are rather stony and gravelly, and are evidently morainal formations (see Plate 2, Fig. 1). The hilly area in the vicinity of the Cypress Hills, however, is not morainal in nature, but was formed by the erosion of the Cypress Hills Plain, and the water-worn stones scattered over this hilly area and right down to the Walsh flats have come from the formation capping the Cypress Hills (see Plate 2, Fig. 2). It will be observed that most of the important sand areas occupy positions adjacent to the main rivers, and were, no doubt, laid down by these rivers. Other sandy and mixed areas are to be found adjacent to lakes, as, for example, the area around Many Island, Sam, and Chappice Lakes. Still other sand and mixed sand areas were probably formed by drainage ways and lakes which have since found other channels or outlets. For example, the mixed area extending north and south from the Bow to the Oldman river, at the western end of the Sheet, is undoubtedly an old drainage way. Many of the leveler areas of intermediate and fine soil were laid down in temporary lakes developed when the glaciers were melting and temporarily damming up the natural outlets.

As previously stated the underlying formations consist largely of sandstones and shales. The sandstones are composed of the finer grades of sand held together by clay, some of which apparently is calcareous. Typical shales are made up largely of clay, but these shales are often very sandy, with clay as the chief binding material. Thus it might be expected that the weathering of these country rocks, and the subsequent mixing and reworking of the materials, would give rise to soils of intermediate character. In some instances the reworking and assorting by water has been carried on to such a degree as to separate the weathered materials into areas of sand and clay, or clay loam. For the most part, however, the soils are intermediate in texture, and intermediate soils are, after all, the most desirable general purpose classes of soils.

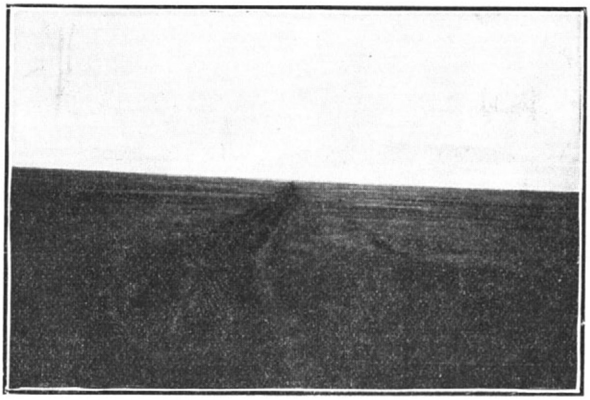

Fig. 1.—Typical level topography of Medicine Hat Sheet.

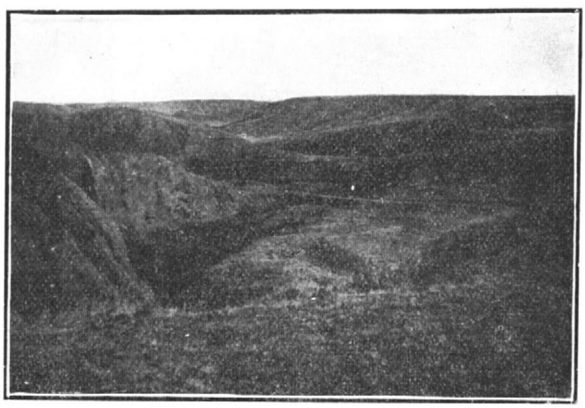

Fig. 2.—Rough topography typical of areas classed as "eroded."

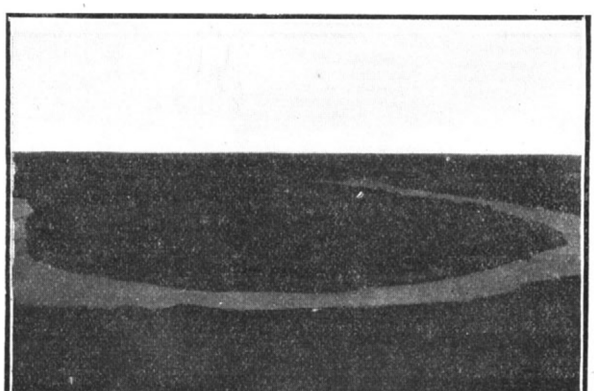

Fig. 3.—Flood plain deposits on South Saskatchewan River, typical of soil classed as "river bottom."

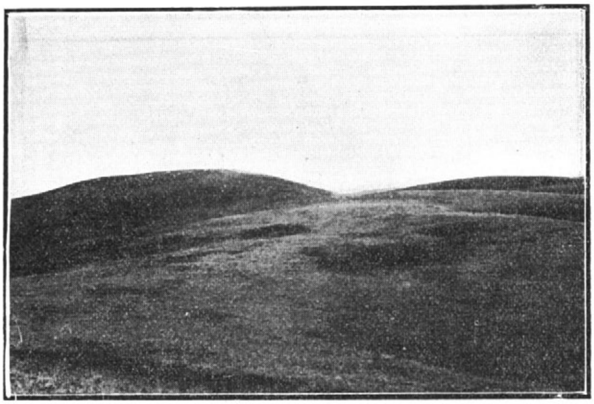

Fig. 1.—Hilly topography, in this case morainal in nature. Note glacial stones.

Fig. 2.—Conglomerate consisting of water-worn stones held together by calcareous cement. Parts of the Cypress Hills are capped with this conglomerate.

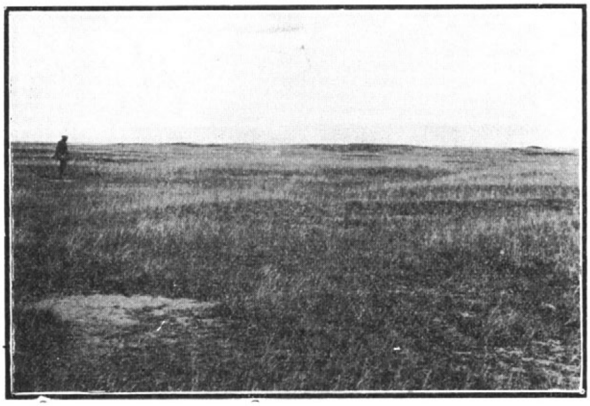

Fig. 3.—"Blowout" area. Note irregularity of vegetation and depressed bare patches from which surface soil has been blown.

The figures in Table VIII show that over two-thirds of the soils of the Medicine Hat Sheet consists of soils of medium to heavy texture, and that almost all of this, or about two-thirds of the area, consists of loam and silt loam. The lighter types, fine sand, and fine sandy loam, constitute about 17 per cent. of the total, while the mixed areas, eroded areas and river bottoms, occupy about 12 per cent. Not more than 4 or 5 per cent. of the soils would be sufficiently heavy to cause much difficulty in tillage operations.

It is rather fortunate that such a large proportion of this area consists of soils of medium to heavy texture with good subsoils, since such soils absorb and carry more moisture from one season to another than do the lighter soils. Most of the soils contain a high percentage of the finer grades of sand, and are naturally well drained.

TABLE VIII.—VARIOUS SOIL TYPES IN MEDICINE HAT SHEET.

Soil Types.	Acres.	% of Total.
Fine Sand	256,300	9.3
Fine Sandy Loam	209,600	7.4
Loam	606,400	22.1
Loam (rolling phase)	294,400	10.6
Loam (hilly phase)	361,600	13.0
Silt Loam	365,400	13.18
Silt Loam (rolling phase)	137,600	4.92
Silt Loam (blowout phase)	135,200	4.9
Clay Loam	11,300	.37
Clay	57,800	2.1
Mixed areas	93,800	3.4
River bottom	13,100	.43
Eroded	219,700	7.8
Lakes	15,500	.5
Total	2,777.700	
Actual area	2,764,800	
Total rolling area	467,800	16%
Total hilly area	390,400	14%

The colors of the soils of this Sheet vary as follows: very dark brown, dark brown, reddish brown, light brown, dark gray. The subsurface soils and subsoils are almost invariably light colored, varying from very light brown to gray or light gray, and in some cases they are almost white.

The organic matter extends down from a few inches to a foot, with an average depth of perhaps six or eight inches. In some instances these soils are deficient in organic matter, and in no instances do they contain as much organic matter as the soils in some other parts of the province, but they are fertile for the most part, and respond with excellent crop growth when the supply of water is sufficient. They are especially well supplied with mineral plant foods (see Table IX). Even the sands of this district are fertile as compared with the average sand soil, but they will not hold up under cropping as well as the heavier classes of soil, and owing to the seasons of low rainfall it is doubtful if these sand areas can ever be profitably cultivated. In no instances are the soils of the district sour or deficient in limestone. The surface layers are lowest in limestone because this constituent is readily leached into the lower layers, and because plants absorb more calcium from the surface than from the subsoil.

FINE SAND

The sand areas constitute about 9 or 10 per cent. of the soils of the Medicine Hat Sheet. They belong chiefly to the fine sand class, since they are made up very largely of fine and very fine sand, but in certain areas they grade into very fine sand, and in other areas into medium sand. The subsurface soil and subsoil, as a rule, have about the same texture as the surface soil, and the sand layer varies in depth from a few feet to upwards of thirty feet, especially in the dune areas. The areas classed as fine sand are, for the most part, fairly uniform in texture, but there are some other areas classed as mixed, which include considerable sand and gravel, as well as heavier patches.

The topography of the sand areas is undulating to rolling, with certain areas of hills and gravelly knolls, and some other rather extensive areas of sand dunes, as indicated on the map.

In color the surface soil varies from dark brown to light brown, and the subsurface and subsoil from light brown to gray. The color of the surface soil is influenced by the amount of organic matter present, and the depth of organic matter varies from practically nothing in some of the active dune areas, to perhaps six or eight inches in the better areas.

The sand areas of this Sheet have been formed by the weathering of the underlying sandstones, chiefly of the Belly River formation. As previously observed, most of the important sand areas occupy positions adjacent to the main rivers, and were, at least in part, laid down by these rivers. The largest of these occurs in the south-west corner of the Sheet, about the junction of the Bow, Oldman, and South Saskatchewan rivers, the largest portion lying south of the Oldman river. Other important areas occur along the South Saskatchewan River north of Medicine Hat, and along the creeks just south of Medicine Hat. Important sand areas occur around Many Island Lake, at the east end of the Sheet, and between the Bow River and Lake Newell in the north-west corner. Other smaller sand areas occur elsewhere.

These sands are incoherent in nature, and blow readily if the grass covering is distributed. Dunes are to be found in parts of most of the large sand areas (see soil map). The dune areas cannot be successfully cultivated and should be kept covered by native vegetation, if possible, to prevent their further spread.

In many places the native vegetation is characteristic of sandy soils in the southern part of the province, and includes sand grass, spear grass and a native legume called buffalo bean. Under grain crops one of the worst weeds of the sand areas is veindock, which in some cases has become such a pest as to virtually inhibit crop growth.

These sands absorb water readily and are naturally well drained, but they do not retain much of the absorbed water. The excess water percolates rapidly until it encounters impervious layers, where it is usually beyond the reach of ordinary crop plant roots. For this reason crops on sands suffer readily from drought. But when supplied with water throughout the growing season these sands produce good crops, for they are relatively fertile, as may be seen from Table IX. Their nitrogen content, however, is only about one-half as great as that of the heavier soils, and constant heavy crops would soon depress the yields.

These sand areas in general prove to be the least profitable of all the soil types, when restricted to straight grain growing. A considerable portion of the sands should be devoted to the production of permanent natural grasses, or such grasses as brome and western rye, for pasture. When grain growing is desired, rye should receive consideration in the cropping system, and a legume such as alfalfa or sweet clover should occasionally be grown. Under irrigation these areas would produce good crops of alfalfa, and should prove profitable, but it is doubtful if much of the sand will ever be irrigated.

FINE SANDY LOAM

The fine sandy loam soils constitute about 7 to 8 per cent. of the area of the Sheet. By definition these soils contain over 50 per cent. of fine sand, and less than 20 per cent. of clay. Such soils are, therefore, fairly light in texture. Generally the subsurface soils and subsoils are heavier than the surface soils, but this is not always the case. There are some small patches within the fine sandy loam areas which are lighter or heavier than the general class, but which are not large enough to outline separately in a survey of this kind. In some cases also, there is no sharp divisional line between different soil classes, but a gradual transition from fine sandy loam into fine sand, on the one hand, or into loam on the other, and in these cases the divisional line was chosen arbitrarily. The soil map shows that in most cases the soil classes adjacent to fine sandy loam are either fine sand or loam. Most of the fine sandy loam areas are to be found in the western half of the Sheet, but there are some areas of this class in the vicinity of Medicine Hat and elsewhere.

The topography of the fine sandy loam areas is nearly all undulating to rolling, though there is a small area of hilly land in the north-west corner of the Sheet.

The color of the surface soil is generally dark brown, but it varies from dark brown to light brown, and the subsurface and subsoil vary from light brown to gray. The organic matter layer varies in depth from about four inches to about one foot.

The fine sandy loams absorb water readily and retain it better than the fine sands, but not as well as the finer soils. The excess water percolates to a depth greater than that of ordinary plant roots, or until it encounters less pervious layers. Hence crops on fine sandy loams suffer more severely from drought than crops on heavier classes of soil, but less severely than crops on fine sands. Furthermore, the average fine sandy loam is more fertile than the average fine sand, being richer in nitrogen, phosphorus, potassium, calcium and magnesium, and for this reason, also, may be expected to produce better crops (see Tables IX and X). Fine sandy loam areas will prove profitable where irrigation water can be applied, as they absorb water readily and retain it moderately well. Over-irrigation, especially where the lighter soil layer is shallow, and rests on an impervious layer, might cause accumulation of alkali salts in restricted areas. Since fine sandy loams are relatively loose and open, and drift rather easily when the organic matter content is reduced, a cropping system should be followed which would tend to maintain the soil's supply of fibre and fertility. Grasses such as brome and western rye, and legumes such as sweet clover and alfalfa, should be grown at intervals in the rotation.

LOAM

The loam areas, apart from rolling and hilly phases, constitute about 22 per cent. of the total area of the Sheet. If the rolling and hilly phases were included, the loams would make up nearly half of the area of the entire Sheet. By definition the loams contain less than 20 per cent. clay, less than 50 per cent. silt, and less than 50 per cent. gravel and sand. The proportions of sand, silt, and clay are, therefore, such as to impart no predominating property of one constituent, and the soil is intermediate in character. In practise of course, the loam areas are not altogether uniform, and this is particularly true of the rolling and hilly phases. There are some patches of loam that are lighter or heavier than the general class, but these are not large enough to outline separately in a survey of this kind. In some cases, also, there is no sharp divisional line between the different soil classes, but a gradual transition from loam into fine sandy loam, on the one hand, or into silt loam on the other hand, and in these cases the divisional line was, of necessity, chosen arbitrarily.

Loam areas are to be found in almost all parts of the Sheet, but aside from the rolling and hilly phases, most of the loam soils are to be found west of Medicine Hat.

Apart from the rolling and hilly phases, the topography of the loams is generally undulating or gently rolling, and, in most places, the land is relatively free from stones and gravel.

The surface soils vary in color from very dark brown to brown, with dark brown predominating, and the subsurface and subsoils vary from brown to light gray, with gray predominating. The organic matter layer varies in depth from about six inches to about one foot, the average depth being closer to the former figure than to the latter.

The loams absorb water readily, and retain fairly large quantities of moisture that may be used by crops in periods of scanty rainfall, or carried over from season to season. In fact the loam and silt loam classes are very desirable from the standpoint of resistance to drought. Furthermore the average loam is relatively fertile (see Tables IX and X). If surface soils are compared it will be observed that loam contains more nitrogen and organic matter than any other soil class except silt loam and clay, and contains about as much phosphorus as any other class except clay. Loans are, therefore, desirable from the standpoint of texture and fertility, and are adapted to a wide variety of crops.

Under irrigation loams are probably as satisfactory as any other class of soil, especially where the subsoil does not differ greatly in texture from the surface soil, as such soils absorb and retain water readily, and may be cultivated when wet without injury to texture. Some of the loam areas at the western end of the Sheet are already being irrigated.

LOAM (Rolling Phase)

The rolling-phase-loam soils constitute about 11 per cent. of the area of the Sheet. There is practically no rolling-phase-loam at the western end of the Sheet, but a good deal at the eastern end, and in the north central portion. These soils may be distinguished from other loams, on the soil map, not by a distinctive color, but by a special cross-hatching.

The description of the characteristics of loam previously given, would also apply fairly well to the rolling-phase-loam. The latter, however, is less uniform than the former. The soil in the lower places between knolls is often finer than on top of knolls, and in some cases the top of the knolls are gravelly. On the whole also, these rolling areas are more stony than the undulating areas. In most places, however, the rolling phase can be cultivated without difficulty, as the slopes are not steep.

LOAM (Hilly Phase)

The hilly-phase loams constitute about 13 per cent. of the area of the Sheet. There is very little hilly-phase loam at the western end of the Sheet, some in the north-central portion, and a good deal at the eastern end. These soils may be distinguished from other loams, on the soil map, by a special cross-hatching.

Although the description of the characteristics of loam previously given would apply to the average hilly-phase-loam soil, it must be stated that the latter is by no means uniform in texture. The soil in the lower places between hills is often finer than on the tops of the hills, although sometimes the hill top soil is quite heavy in texture. In some cases the tops or hills are gravelly or stony, and on the whole the hilly land is more stony than the undulating or rolling land. Although there are many small areas among the hills that can be cultivated satisfactorily, the hilly areas, on the whole, are too steep to be cultivated economically.

SILT LOAM

The silt loam areas, apart from rolling and blowout phases, constitute about 13 per cent. of the total area of the Sheet, and if the rolling and blowout phases were included, would make up nearly a quarter of the area of the entire Sheet. Together they form the second most extensive class of soil in the Medicine Hat Sheet. By definition the silt loams contain less than 20 per cent. clay, and more than 50 per cent. silt. The predominating constituent is silt, which constituent naturally gives to the soil its characteristic property. The soil texture is, therefore, fine, but only moderately sticky. The silt loam areas, like other areas, are not altogether uniform, and this is particularly true of the rolling and blow-out phases. There are some patches of silt loam that are lighter or heavier than the general class, but which are not large enough to outline separately in a survey of this kind. In some cases, also, there is no sharp divisional line between different soil classes, but a gradual transition from silt loam into loam, or other soil classes, but usually into loam. The subsoils are usually heavier than the surface soils and could be classed, in most cases, as heavy silt loam, or silty clay loam. For the most part the subsoils are fairly uniform in texture with high proportions of silt.

There is a fairly large area of silt loam soil north of the Cypress Hills, in the south-east corner, and there are some large areas north and south of the South Saskatchewan River, in the central portion of the Sheet, as well as several other smaller areas in various places at the western end of the Sheet.

Apart from the rolling phase, the topography of the silt loam is generally undulating or gently rolling, and in most places the land is relatively free from stones and gravel. There are some water-worn stones from the Cypress Hills formation scattered over the silt loam area north of the Cypress Hills, but not enough to interfere seriously with cultivation.

The surface soil varies in color from brown to very dark brown, with dark brown predominating, and the subsurface soils and subsoils vary from brown to light gray, with gray predominating. The organic matter layer varies in depth from about six inches to about one foot, the average depth being closer to the former figure than to the latter.

The silt loams absorb water rather readily and retain fairly large quantities of moisture that may be used by crops in periods of scanty rainfall, or carried over from season to season. On the whole, there is probably no more desirable class of soil, from the standpoint of resistance to drought, than a silt loam with a deep silty subsoil. Heavier soils absorb more water, but the rate of absorption is slower, run-off losses are greater, and plants cannot extract as much water from heavier soils, as it is held more tenaciously by the finer soil particles.

The average silt loam is relatively fertile (see Tables IX and X). If surface soils are compared it will be observed that silt loam contains more nitrogen than any other soil except clay, and contains as much phosphorus as any other soil except clay. Silt loams are, therefore, desirable from the standpoint of fertility as well as texture, and are adapted to a wide variety of crops.

Under irrigation silt loams, like loams, are as a rule as satisfactory as any other class of soil, especially when the subsoil does not differ greatly in texture from the surface soil. Such soils absorb and retain water readily, and may be cultivated when wet without serious injury to texture. Some silt loam soil in the north-west corner of the Sheet is already irrigated, and much more soil of this class will be irrigated when the Canada Land and Irrigation Company canal is carried east across the Bow River at Ronolane.

SILT LOAM (Rolling Phase)

The rolling-phase silt loams constitute about 5 per cent. of the area of the Sheet. There is a fairly large area of this class of soil north of the Saskatchewan River, near the centre of the Sheet, and there are other areas of rolling-phase silt loam north of the Cypress Hills, in the south-east corner. These areas may be distinguished from ordinary undulating silt loams, on the soil map, not by a distinctive color, but by a special cross-hatching.

The description of the characteristics of silt loam previously given would also apply fairly well to the rolling-phase silt loam. The latter, however, is less uniform than the former, and, on the whole, the rolling areas are more stony than the undulating areas. In most places, however, the rolling phase can be cultivated without difficulty, as the slopes are not steep.

SILT LOAM (Blowout Phase)

The rather large area in the north-west quarter classed as blowout-phase silt loam, and distinguished on the map by a special color, constiuites about 5 per cent. of the total area of the Sheet. Many areas of soil of this peculiar nature are to be found in south-eastern Alberta, in the other prairie provinces and the United States, and in other parts of the world. Numerous shallow depressions or "blowout spots" varying in depth from about six inches to about eighteen inches, irregular in shape, but varying in diameter from about five feet to about fifteen feet or more, are to be found throughout the entire area (see Plate 2, Fig. 3). In some places these depressed spots are very numerous and make up nearly half the entire surface, but for the most part they are not so numerous, and in some places there are only a few scattered depressions or "blowouts."

Depressed spots of this nature are given various names, such as "blowouts," "burnouts," "slick spots," etc. Often the depressions are almost bare ,or but scantily covered with grass, although the surface soil round about is covered by prairie grass. An examination of the soil structure reveals the fact that the surface of the depression is usually rather fine and impervious in nature, and this rather impervious layer extends for some distance underneath the surface layer surrounding the depression, and may form a continuous subsurface layer between depressions. As a rule the surface soil between depressions is distinctly more open in texture, and when soils of this class are plowed and cultivated for some years the depressions are filled in, the finer and coarser layers are mixed up, and the resulting surface soil could properly be classed, in this area, as silt loam. But because of the lack of grass in the depressed spots, and the rather undesirable nature of the subsurface layer, this class of soil, when first brought under cultivation, is not as fertile, nor as desirable in texture as ordinary silt loam. The surface soil is lower in nitrogen than any other class of soil except fine sand (see Table IX).

We have called these spots "blowouts" rather than "burn-outs," as it seems unlikely that the depressions could have been burned out, since the surface layer between the depressions consists of soil which is not exceptionally rich in combustible organic matter, and could not possibly be burned off to the depth of the depressed spots. On the other hand, when rain falls, puddles are formed in depressions, and it is suggested that this water and the "alkali" salts which tend to accumulate in the depressions have kept down the growth of grass, and have thus permitted the looser surface soil to blow away from these spots, and form the so-called "blow-outs."

CLAY LOAM

Less than half of one per cent. of the area of the Medicine Hat Sheet has been classed as clay loam, and this soil class is, therefore, relatively unimportant in this Sheet. There are a few rather small clay loam areas in various parts of the Sheet, and these usually consist of flats or low lying land.

By definition clay loams contain 20 to 30 per cent. of clay, and they are, therefore, somewhat sticky and rather heavy to work, and should not be cultivated when too wet ,as this would injure the soil texture, at least temporarily. Some of the low-lying clay loam flats contain a good deal of salt, and for this reason are not as productive as they would be otherwise. These heavier soils, however, can withstand more "alkali" salt than the lighter soil classes, and clay loams are also fairly resistant to drought as they absorb and retain a good deal of moisture.

CLAY

No very extensive areas in the Medicine Hat Sheet have been classed as clay, the clays altogether making up only about 2 per cent. of the total area of the Sheet. It will be noted, however, that there is several times as much clay as of clay loam. Clay areas are to be found in various parts of the Sheet. They are all rather small, and consist of depressions or flats in nearly all cases. There are several small areas of clay near the northern border of the Sheet, towards its western end, and there are several large clay flats south and east of Medicine Hat. The most notable of these is Walsh flat, which originates in Saskatchewan and extends from the eastern end of the Sheet westward for a distance of about twenty miles towards Medicine Hat. It is traversed by the C.P.R. main line.

The soil of these clay flats is exceedingly heavy and tenacious, and is worked with some difficulty. By definition, any soil which contains over 30 per cent. of clay is classed as clay. Such soils must be handled carefully and should not be worked when too wet, as this injures the soil texture. The disc plow may be advantageously substituted for the mould board plow in these areas. On account of the difficulty of working, only a small percentage of these soils has ever been cultivated, although these clay soils, as represented by a sample from Walsh flat, are exceptionally fertile.

MIXED AREAS

The areas outlined as mixed constitute about 3 to 4 per cent. of the total area, and are, therefore, more extensive than the areas classed as clay or clay loam. Mixed areas are to be found in many parts of the Sheet, and they consist of more than one, and usually several, classes of soil, so mixed together as to make it impossible to outline each class separately in a survey of this kind. In some cases it would be necessary to call the areas mixed, even with a detailed survey, as it would be impossible to establish boundaries between different soil classes. No doubt most of the mixed areas were formed as a result of the sorting action of water during glacial or more recent times. For example, the rather sandy mixed area around Sam and Chappice lakes was undoubtedly formed as a result of the sorting action of the lake water, and the somewhat gravelly mixed area extending north and south from the Bow to the Oldman rivers at the western end of the Sheet, is undoubtedly an old drainage way.

ERODED AREAS

The eroded areas constitute about 8 per cent. of the total area of the Sheet, and occur chiefly along or adjacent to rivers and smaller drainage ways (see Plate 1, Fig. 2.) In some cases these areas consist of clay subsoil from which the surface soil has been washed away, or sand banks through which the streams have cut, or early flood plains, and in many places boulders, stones, or gravel have been left exposed upon the surface. In other places the banks are relatively free from stones, and are fairly smooth and loamy in character. For the most part, however, the eroded areas are composed of land which, because of its steep, rough, or stony character is difficult or impossible to till.

RIVER BOTTOMS

The river bottoms constitute nearly half of one per cent. of the total area, and occupy chiefly the flood plains of the later stages of the streams (see Plate 1, Fig. 3). The soil material varies greatly from place to place and may consist of clay flats, silts, sands, gravels, stony patches, boulder heaps or any of the intermediate admixtures. Some of the river bottom areas are very good farming lands, while others cannot be tilled and are useless for anything but pasture.

COMPOSITION OF SOILS OF MEDICINE HAT SHEET

The average chemical compositions of the soils of the Medicine Hat Sheet are given in Table IX.

It may be seen from Table IX that for all types of soil the nitrogen content is highest in the surface and lowest in the subsoil. This is accounted for by the fact that nearly all of the nitrogen is held in the form organic matter, and most of the organic matter is to be found near the surface. There is a gradual decrease in nitrogen from surface to subsoil, and in general the surface contains two to three times as much nitrogen as the subsoil. If the soil classes are placed in order of decreasing percentages of nitrogen they will stand as follows: clay, silt loam, loam, fine sandy loam, silt loam (blowout phase), fine sand. The clay contains most nitrogen and the fine sand least.

The average phosphorus is about the same for the surface, subsurface, and subsoil of any one soil type, and the various soil types do not differ markedly, although here again the clay contains most and the fine sand least. Our best Alberta soils contain about twice as much phosphorus as the average shown in Table IX, and our poorest only about two-thirds as much.

TABLE IX.—AVERAGE CHEMICAL COMPOSITION OF THE VARIOUS SOIL TYPES.

Depth	Nitrogen %	Phosphorus %	Potassium %	Calcium %	Magnesium %	Carbonates in terms of $CaCO_3$ %
FINE SAND (2 samples)						
Surface	.101	.036	1.12	.52	.18	.033
Subsurface	.037	.037	1.07	.58	.20	.023
Subsoil	.031	.033	1.11	.63	.16	.360
FINE SANDY LOAM (2 samples)						
Surface	.123	.044	1.45	.70	.29	.017
Subsurface	.085	.046	1.48	1.92	.61	3.92
Subsoil	.041	.047	1.46	2.95	.79	6.95
LOAM (16 Samples)						
Surface	.147	.045	1.45	.65	.38	1.18
Subsurface	.092	.048	1.41	1.92	.60	4.08
Subsoil	.058	.052	1.38	3.05	.80	7.24
SILT LOAM (11 Samples)						
Surface	.161	.046	1.54	.69	.41	.37
Subsurface	.099	.047	1.57	1.78	.65	3.23
Subsoil	.067	.051	1.57	2.44	.74	6.08
SILT LOAM BLOWOUT PHASE (3 Samples)						
Surface	.111	.045	1.51	.86	.53	.70
Subsurface	.085	.044	1.41	2.41	.69	5.68
Subsoil	.048	.050	1.44	2.12	.80	4.48
CLAY (1 Sample)						
Surface	.255	.069	1.83	1.03	1.04	.275

NOTE: Surface 0 to 6 2/3 inches; Subsurface 6 2/3 to 20 inches, and Subsoil 20 to 40 inches.

The calcium and magnesium, as a rule, are lowest in the surface soils and highest in the subsoils, whereas the phosphorus and potassium are about equally abundant in the surface and subsoils. This is accounted for by the fact that the former two elements are much more soluble than the phosphorus or potassium of the soil, and any rain penetrating the soil carries them downwards. Again, the quantities required to produce the native grasses and farm crops are taken largely from the surface soil. Many of the surface soils contain twice as much calcium as magnesium, and many of the subsurface and subsoil samples contain three times as much calcium as magnesium. The magnesium of the soil is less soluble than the calcium, and the plants demand less magnesium than calcium; thus the ratio is narrower in the surface than in the subsoil. It should be noted that none of the soils of this Sheet are deficient in either calcium or magnesium.

The potassium as a rule is slightly higher in the surface than in the subsoil, but the differences are small. The finer textured soils contain more potassium than the coarser soil-clay having the highest percentage and fine sand the lowest.

The carbonates, expressed as calcium carbonate (limestone), are lowest in the surface and highest in the subsoils. The reason for this is given above under the statement about calcium and magnesium. In no cases were the soils of this sheet found to be acid. However, on the other hand they are not so high in carbonates (limestone) as are the soils of the Macleod Sheet to the west. The Belly River formations underlying much of the Medicine Hat Sheet are not nearly as rich in limestone as are the newer formations which underlie the soils of the Macleod Sheet.

The fine sand (Table IX) contains the lowest amount of carbonate, .033 per cent. in the surface. This is equal to about 1/3 ton of limestone. The loam is highest with 1.18 per cent., or about 11 tons per acre. There is sufficient limestone in all these soils to permit the growth of legumes.

If we consider the chemical composition of the surface soils only, taking each element in turn, and arranging the various soil classes in order of decreasing percentages, they will stand as follows:

TABLE X.—COMPARATIVE CHEMICAL COMPOSITION OF THE VARIOUS SOIL TYPES.

(In order of decreasing per cent.)

	1	2	3	4	5	6
Nitrogen	C. .255	SiL. .161	L. .147	F.S.L. .123	SiL. B.O. .111	F.S. .101
Phosphorus	C. .069	SiL. .046	SiL. B.O. .045	L. .045	F.S.L. .044	F.S. .036
Potassium	C. 1.83	SiL. 1.54	SiL. B.O. 1.51	L. 1.45	F.S.L. 1.45	F.S. 1.12
Calcium	C. 1.03	SiL. B.O. .86	F.S.L. .70	SiL. .69	L. .65	F.S. .52
Magnesium	C. 1.04	SiL. B.O. .53	SiL. .41	L. .38	F.S.L. .29	F.S. .18
Carbonates in Terms of $CaCO_3$	L. 1.18	SiL. B.O. .70	SiL. .37	C. .275	F.S. .033	F.S.L. .017

C.—Clay.
SiL.—Silt Loam.
SiL. B.O.—Silt Loam (blowout phase).
L.—Loam.
F.S.L.—Fine Sandy Loam.
F.S.—Fine Sand.

All the elements mentioned in Table X are least abundant in fine sand and most abundant in clay. As a rule, fine sand is the least productive type in the area surveyed. Next to fine sand, fine sandy loam is usually poorest in essential elements. The clay, because of its physical nature, is not an altogether desirable type. Apart from clay, the elements needed for crop growth are most abundant in silt loam.

Again we may make another kind of comparison showing the relation between the supply of essential elements present in the soils and the quantities required by crops. From the per cent. of any essential element found in the soil and the crop, it is not difficult to calculate the quantity present in a given depth and area of soil, and how many crops such a soil could theoretically produce. For example, a thirty-bushel crop of wheat, including straw, would require about 57 pounds of nitrogen, 9 pounds of phosphorus, 6.3 pounds of calcium, 4.8 pounds of magnesium, and 35 pounds of potassium. The average soil to the depth of 6 to 7 inches would weigh 2 million pounds per acre. Thus by using the data in Table IX, we may construct Table XI, from which we find that the average fine sandy loam from the Medicine Hat Sheet contains, in the surface, enough nitrogen to produce 43 thirty-bushel crops of wheat, enough phosphorus for 98 crops, enough calcium for 2220 crops, enough magnesium for 1210 crops, and enough potassium for 830 crops.

For the various soil types the number of thirty-bushel crops of wheat that could theoretically be produced from the surface are shown in Table XI.

TABLE XI.—THEOROTICAL NUMBER OF THIRTY BUSHEL CROPS OF WHEAT FROM SURFACE LAYER OF VARIOUS SOILS.

Type	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
F.S.	35 crops	80 crops	640 crops	1650 crops	750 crops
F.S.L.	43 "	98 "	830 "	2220 "	1210 "
L.	51 "	100 "	830 "	2060 "	1580 "
SiL.	56 "	102 "	880 "	2190 "	1710 "
SiL. (B.O.)	39 "	100 "	860 "	2730 "	2920 "
Clay	89 "	153 "	1050 "	3270 "	1150 "

Apart from water the only soil elements essential for plant growth other than those given in Table XI, are sulphur and iron, and it is seldom considered worth while to determine the quantities present since most soils contain large quantities as compared with the amounts required by crops.

From these figures and statements it might seem as though the supply of essential elements, other than nitrogen and phosphorus, is practically inexhaustible. However, the fact of the matter is that crop growth may be retarded by the lack of a certain element, even though there is enough of that element present to produce hundreds of crops. The explanation for this is that the essential element dissolves slowly or becomes available slowly. It should be noted here that the rate of solution can often be hastened by better methods of tillage and soil management, and by rotation of crops. The decomposition of organic matter is more intense in fallow soil and under tilled crops than under untilled crops. It is likewise more rapid under legumes than under cereals.

Although the importance of soil moisture as a limiting factor in crop production in Alberta, and particularly in southeastern Alberta, should be emphasized, the importance of soil fertility should not be lost sight of. Because of the limited amount of leaching the soils usually contain considerable quantities of the soluble salts essential for plant growth, and in years of abundant rainfall large crops are produced. However, it is important to realize that the total quantities of some important plant food elements are not any greater than in good soils of more humid regions, as may be observed in Table XII.

TABLE XII.—CHEMICAL COMPOSITION OF SEVERAL NORTH AMERICAN SURFACE SOILS.

	Nitrogen %	Phosphorus %	Calcium %	Magnesium %	Potassium %
Medicine Hat Sheet, Alberta, Loam	.147	.045	.65	.38	1.45
Edmonton, Alberta, Loam	.620	.108	1.22	.62	1.49
Guelph, Ontario, Loam	.181	.097	1.39	.40	1.66
Illinois, U.S.A., Brown Silt Loam	.247	.054	......	......	1.78

The element most deficient, in relation to crop needs, is nitrogen, and it will be observed that the percentages of nitrogen in the soils of the Medicine Hat Sheet are not greater than in many soils of humid regions. This helps to explain why, under irrigation, wheat growing alone very quickly becomes unprofitable. In a very few years nitrogen becomes a limiting factor, and large crops of wheat cannot be produced even with an abundant supply of water. It is, therefore, important, if crop growth is not to be limited by lack of nitrogen, to begin growing a legume, such as alfalfa, within a few years from the time that irrigation water is first applied.

The nitrogen figures also indicate the desirability of growing a legume such as sweet clover, occasionally, even where dry farming is practised, in order to maintain the nitrogen as well as the fibre content of the soil. Of course it will be understood that continuous wheat growing will not exhaust the soil's nitrogen supply under dry farming conditions as quickly as under irrigation.

LOSS OF ORGANIC MATTER AND ITS RELATIONSHIP TO LOSS OF FERTILITY

The one-crop grain farming system followed so largely in the west, tends to reduce the soil's supply of organic matter, and of nitrogen also, since the soil-nitrogen is very largely held in the form of organic matter. Organic matter is constantly decaying in the soil, and the only source which tends to replenish the supply is the stubble and roots of grain together with any resdue from weeds that may have grown on the land. When the land is fallowed the increased air and moisture favor a more rapid decomposition of the organic matter, and at the same time no organic matter is added to replace that decomposed. It is, therefore, not difficult to understand why this system of farming tends to exhaust the soil's supply of readily decomposable organic matter.

Dr. Shutt shows that soils from Portage la Prairie lost 22 per cent. of its nitrogen in the twenty-five years it had been cropped and fallowed; or the nitrogen content fell from .651 to .506 per cent. This is equal to about 2900 pounds per acre for the surface soil.

Much of the nitrogen reported in the above loss could not be accounted for in the crops produced. Thus it can be seen that the straight grain system is rather extravagant with the soil's organic matter. Rotations including sod-forming crops and summer fallow substitutes would be more conservative.

The decomposition of organic matter in soils is a necessary process, and a soil's producing power depends, in a large measure, upon the decomposition of organic matter in that soil. Non-legumes depend for their nitrogen supply upon the nitrates set free when organic matter decomposes. The mineral plant foods are likewise made more available when the organic matter decomposes. As pointed out elsewhere, the total stores of mineral matter in most soils are large in comparison with what the crop removes, but crop growth depends upon the supply of essential elements dissolved in the soil water. When organic matter decomposes in soil it sets free a quantity of mineral salts which dissolve readily in the soil water and supply the growing plants with required nutrients.

Organic matter increases a soil's water-holding capacity, and it is very important that the soil should retain as much of the rainfall as possible, since moisture supply so often limits crop production. The average soils may hold from 15 to 40 per cent. of water when saturated, whereas organic matter may hold from 50 to 200 per cent. at saturation.

The amount and condition of the organic matter materially affects the ease with which soils will drift. (See Soil Drifting.)

For the above reasons an attempt should be made to maintain the soil's supply of organic matter. This might best be done by modifying the straight grain system so that it consisted of rotations, including sod-producing forage crops and summer fallow substitutes, as well as a winter cereal such as rye. Among the most promising grass crops Brome and Western Rye are worthy of mention.

SOIL DRIFTING

Soil drifting is not as serious a problem in the Medicine Hat Sheet as it is in the areas to the west. Nevertheless soil drifting is a serious menace and does considerable damage in seasons of high winds. The principal sand dune areas are indicated on the map by special legends.

All soil types appeared to drift provided they had been cropped for a number of years and happened to be in a fine loose, dry condition when swept by strong winds. Some types drift earlier after breaking than others. Some likewise drift more severely than others. The sands start very shortly after breaking, whereas a number of years may elapse before the finer types are affected. The lighter types and the heavier types of soil are more severely affected than those of intermediate texture. Some parts of the sand areas are so loose that they have drifted even before breaking.

As previously stated, there are a few very sandy districts in which the soil drifted before it was brought under cultivation, but for the most part drifting did not occur until the sod was broken for grain growing. The original soil was full of root fibre, and the grass covering the surface held the soil. Harrison, of Manitoba, reported that "any type of soil would drift: first, if it had been under continuous grain cropping for a number of years; secondly, if the season was such that it caused the soil to disintegrate; and thirdly, if there were high winds during the months of May and June. The sandy and sandy loam soils were more readily affected by these conditions than the loams and clay loams.

"The period which elapsed after breaking before the sod drifted varied from 5 to 15 years. The average was about 10 years. The drifting did not start until after the virgin fibre disappeared. The continuous cropping and summerfallow system was responsible for starting of drifting earlier than any other cause."

The drifting of soil is not confined to southern Alberta alone. All prairie provinces as well as the dryer portions of the Great Plains area and parts of the Great Basin region of the States have been subjected to soil drifting. Bracken, in Saskatchewan, reports an area of 50,000 acres virtually devastated by soil drifting. Jardine reports 64,000 acres in one block in Kansas. Fairfield states that 75,000 acres in Alberta were ruined for crops in 1920. This is only a portion of the real damage caused by high winds blowing across fine dry soil with no protection from crops and windbreaks.

The summerfallow has undoubtedly been directly responsible for the menace of soil drifting, but we cannot dispense entirely with it; thus it would seem that we are justified in somewhat modifying it.

The longer we cultivate our soils the greater will become the tendency for them to drift, but fortunately by somewhat modifying our present system we can lessen and finally minimize this menace. Discussions of the ways of controlling soil drifting have elsewhere occurred in printed form, but it is not out of place to briefly mention a summary of these control measures as follows: Regulate time of plowing so that the soil is moist when plowed. Leave the surface rough; beware of implements which pulverize the surface soil. Control weeds on summerfallow by using such implements as rod. weeder, duckfoot cultivator, etc., which do not disturb and pulverize surface soil. At critical time, as during winter and early spring, keep soil ridged at right angles to prevailing wind by using lister plow, or other implement; even the springtooth harrow may do, provided the surface is moist. Spread manure on spots most likely to start blowing. Sow a very light crop of oats on summerfallow land in the early fall.

Alternate strips of crop and fallow at right angles to prevailing wind. Do not have very large areas of fallow in one field, or in adjacent fields. Use summerfallow substitutes such as corn, sunflowers, sweet clover. Use systematic rotations, including a certain amount of grass crops, and keep some live stock, thus maintaining the fibre in the soil. Include a fall cereal, such as rye, in the rotation. Plant more trees for wind breaks. Irrigate as much land as possible.

CROP ROTATION

It has been shown experimentally that a crop will give a higher yield if it is grown in rotation with other crops than if it is grown year after year on the same soil. For example, the wheat yields in the much quoted long term Rothamstead experiments were decidedly greater when grown in rotation with other crops than when grown year after year on the same plot. Some of the reasons for such increased yields, and some advantages of rotations, will now be briefly reviewed; without, however, attempting to discuss the relative merits of special rotations.

A good rotation of crops will nearly always include a sod-farming grass or clover crop. Such crops tend to increase the soil's supply of organic matter, the importance of which, in relation to maintenance of soil fertility and preventing of soil drifting, has already been discussed.

If a legume, such as alfalfa, sweet clover, or red clover, can be successfully grown, it should be included in the rotation because such crops are able to obtain their nitrogen supply from the air, and may therefore be used to increase the supply of nitrogen in the soil available for other crops.

Certain insect pests, plant diseases, and weeds naturally accompany certain crops, and do not accompany other crops. By rotating the crops it is, therefore, often possible to escape much of the damage which would be done by the accumulation of these pests, where the crop is grown year after year on the same ground.

In places where the rainfall is sufficient to produce crops without fallowing, a cultivated crop, such as corn, is nearly always included in the rotation thus enabling the farmer to kill the weeds which usually accumulate in crops which are not intertilled. A well cultivated fallow will kill accumulated weeds, but, in many instances, in the district surveyed, it will undoubtedly be found possible to reduce the frequency of fallowing, and possible in some instances, displace fallowing altogether by growing intertilled crops, such as corn.

Then again a crop rotation means a variety of crops, and a variety of crops means less danger of complete loss of crops. Moreover, a variety of crops usually means live stock farming, which is a much safer and more permanent system than the system of grain farming alone, which is commonly followed. (Information as to rotations adapted to the Medicine Hat Sheet may be obtained by writing to the nearest experimental station, or to the district agricultural representative.)

SUMMERFALLOW

By carefully controlled experiments it has been found that growing plants utilize a surprisingly large amount of water. The amount utilized varies with the kind of crop and the growing conditions. The average of many determinations and many crops is over 400 pounds of water for each pound of dry matter. The water must pass from the soil into the plant roots and out through the leaves. This quantity of water thus transpired for each pound of dry matter produced is known as the transpiration ratio. Using this figure and a given weight for a given crop we can calculate roughly how much water would be transpired by that crop. Thus, for example, a thirty-bushel crop of wheat, including grain and straw, would contain at least 5,000 pounds of dry matter, and require 1,000 tons, or about 9 acre-inches of water. There are additional losses of water from soil caused by evaporation and run-off. These added losses would bring the above figures somewhat higher.

It has been shown (see page 17) that, under actual farming conditions in southern Alberta the wheat crop has required, not 400 pounds of water, but about 1,700 pounds of water to produce one pound of dry matter, or twice this amount to produce one pound of grain and one pound of straw, and the farmer has received only about 1.1 bushels of wheat for each inch of rainfall. It would thus seem that the utmost effort should be made towards greater efficiency in the use of our rainfall. Considerable losses, due to evaporation and run-off are unavoidable, but better rotations and soil management would materially reduce moisture losses. The margin of precipitation over actual crop needs throughout the areas surveyed is small during the average season. The average annual precipitation is about 11.3 inches, and since it often drops below this amount it is not strange that the summerfallow must be resorted to. However, the fallow must be better managed than in the past if we are to expect the most efficient use of the rainfall.

The main objects of the summerfallow are to collect moisture for the next season's crop, and to increase the availability of the plant foods. When land is plowed and kept free from weeds the water which normally would pass out through the plants is kept in the soil, provided, of course, the soil is of a retentive nature. It is quite evident that early plowing or cultivation of the fallow is important, because it stops the loss of water caused by the transpiration of growing plants. Weeds, when permitted to grow on the fallow, pump water from the soil in exactly the same manner as any of the crops, and thus defeat the main object of the summer fallow. If a soil sample from a good fallow is compared with a sample from a weedy fallow or a cropped soil, it is found that the good fallow sample contains much more moisture than either of the other samples.

Since a good fallow has a higher moisture content and better conditions for the decomposition of organic matter, it is found to contain more available plant foods than a poor fallow or cropped soil. From published data of the Soils Department of the University, fallow at Edmonton was found to contain from 5 to 10 times as much soluble nitrate nitrogen as cropped soil at the end of the growing season. Data from soils collected from the southern end of the province show fallow to contain at least three times as much nitrates as cropped soil.

For a detailed discussion of the summerfallow practice, see "Summerfallow in Southern Alberta," by James Murray, issued by the Provincial Department of Agriculture.

IRRIGATION

The Medicine Hat Sheet contains extensive areas of irrigable land (see Table XIII). The figures in this Table were obtained from maps and tables in recent Annual Reports of the Reclamation Service, Department of the Interior, and from officials of this department. In some cases the irrigation schemes have been constructed, or at least partly constructed, whereas in other cases of projected districts, the areas have simply been surveyed. As yet only a small proportion of the constructed or partly constructed schemes is actually being irrigated. The larger irrigation areas extend across the border into other Sheets, and for this reason it was necessary to estimate from maps the proportion of each district lying within the Medicine Hat Sheet. The Canada Land and Irrigation Company scheme and the C.P.R. Eastern Section are the principal irrigation areas of this Sheet in operation at the present time. That part of the Canada Land and Irrigation Company project which lies east of the Bow River and north of the South Saskatchewan River is not yet connected with the main canal, as the flume across the Bow River has not been completed. There are a few small private irrigation areas in the eastern half of the Sheet, in creek flats and elsewhere, that are being irrigated at the present time, but the total area of these is quite small.

TABLE XIII.—IRRIGABLE LAND IN THE MEDICINE HAT SHEET.

Constructed or Partly Constructed Districts	Total Irrigable Area of Scheme.	Estimated Irrigable Area Within Sheet
C.P.R. Eastern Section	400,000 acres	108,000 acres
Canada Land & Irrigation Co.	203,000 "	170,000 "
Taber	17,000 "	1,500 "
Projected Districts.		
Lethbridge Southeast	350,000 "	100,000 "
Medicine Hat Southern	7,000 "	7,000 "
Medicine Hat Eastern	4,000 "	4,000 "

The soils of the Medicine Hat Sheet, in general, are well adapted to irrigation, since the majority of them are intermediate in texture and relatively free from boulders. They absorb water freely and possess rather a high retentive power. In many cases, however, they could be improved by the addition of organic matter which under irrigation merely means systematic rotations and livestock. These soils being rich in limestone are well adapted to the growth of legumes, especially alfalfa.

While the district covered by this survey is primarily a grain growing region, it should be emphasized that the success of irrigation will depend upon the decrease in acreage of

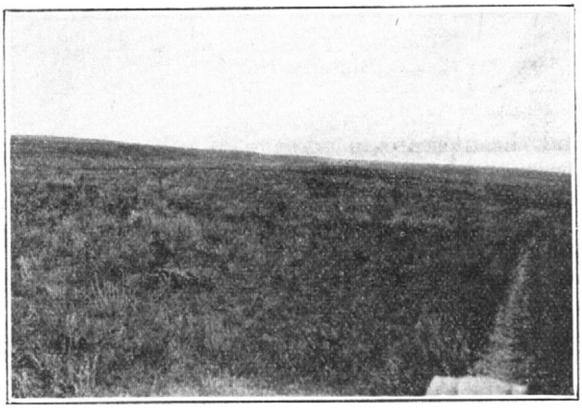

Fig. 1.—Typical prairie before irrigation.

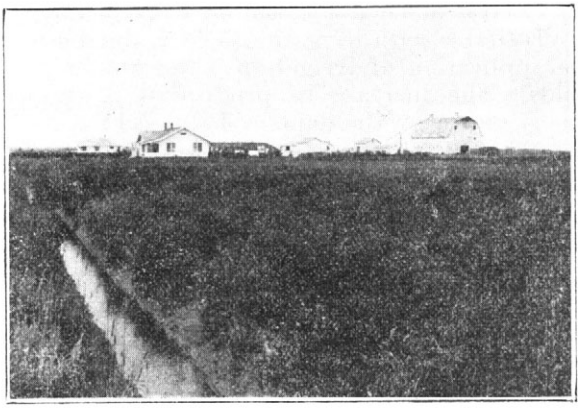

Fig. 2.—Typical prairie a few years after applying irrigation.

Fig. 3.—Note the alkali salts on the dry bed of the lake, giving the appearance of snow.

grains and the increase in acreage of other crops. With the use of irrigation waters a great diversity of crops can be produced, and likewise more intensive methods pursued. At least three or four times the farming population can be maintained under irrigation than would be possible under dry farming. Plate 3, Figs. 1 and 2, show the rapid transformation that has taken place within a few years after irrigation had been applied to the prairie soils of southern Alberta.

The rainfall of this district is not always adequate for the profitable production of crops. Without irrigation it is necessary to have a considerable proportion of fallow, while with irrigation a crop is produced every year. The very poor years are failures under dry farming, whereas they should be the most profitable with irrigation. Even during the average years the application of irrigation water would increase the crop yields. The increase in productive power caused by irrigation is shown by the data in Table XIV.

TABLE XIV.—YIELDS OF VARIOUS CROPS UNDER DRY FARMING AND IRRIGATION—BUSHELS, PER ACRE.

Crop	Lethbridge		Brooks		Ronolane	
	Dry	Irr.	Dry	Irr.	Dry	Irr.
Wheat	30	53	6	41	20	46
Oats	70	108	5	87	38	95
Barley	43	78	5	47	21	61
Peas	27	41	4	49	20	44
Potatoes	237	487	110	244	113	368
Alfalfa*	......	......	.30	4.7	63	3.47
Sugar Beets*	......	......	......	......	7.45	14.86

*Tons per acre.

The yields from the Lethbridge Experimental Station are reported in the Annual Report of the Lethbridge Board of Trade for 1919, and are the average of 11 years (1908-1918). Those from Brooks are computed from graphs in Bulletin 6, Reclamation Service, Department of Interior, and are averages for 4 years. The figures for yields under irrigation are the averages of all plots receiving more than one acre-foot of water. The yields from Ronolane are reported by R. C. Porter, in the Irrigation Review, December, 1922, and are averages of 6 years.

These yields were produced on small areas and are therefore somewhat greater than the average farmer would receive; however, the relationship between dry and irrigated crops expressed in terms of percentage would hold for actual farm practice. For the average of the experimental farms above reported such increase due to irrigation would be approximately 400 per cent.

It is apparent that a number of problems will arise in connection with the development of irrigation, and in certain restricted areas over-irrigation and alkali will cause some difficulty.

ALKALI

All soils are formed from weather rock materials, and alkali salts come originally from decomposed rocks. Many of the stratified rocks such as shales, contain various salts because of their having been formed in salt waters. Soluble salts set free by the decomposition of such rocks tend to accumulate wherever the rainfall is not sufficient to dissolve and carry off the salts.

Alkali lands usually occur where the annual rainfall is less than twenty inches. Alkali does not generally occur on hills or slopes, but rather in the valleys or depressions among the hills or undulations, where such depressions receive the drainage from the surrounding soils and there is no drainage outlet. Such an alkali lake is shown in Plate 3, Fig. 3.

However, alkali frequently occurs on level land, if not too well drained, even though that land is elevated. Porous soils, like sands and sandy loams, other conditions being equal, are less apt to contain injurious quantities of alkali than fine textured soils.

The alkali salts are commonly classed as brown, black or white. Brown alkali consists chiefly of the nitrates. Black alkali consists chiefly of the carbonate and bi-carbonate of sodium, and owes its name mainly to the fact that when this alkaline salt is present it dissolves organic matter and produces a dark brown to black color. White alkali consists chiefly of the neutral salts, such as sodium sulphate, sodium chloride, magnesium sulphate, magnesium chloride, and the similar salts of calcium, and even at times potassium. The main salts of both the brown and white alkali are neutral in reaction and not alkaline, as is the case with black alkali.

Black alkali is the most toxic, and when present in quantities exceeding .1 of one per cent. is usually detrimental to plant growth. The white alkali is least toxic and seldom causes injury unless present in quantities exceeding .5 of one per cent. Black alkali deflocculates fine textured soil, and causes them to become tough and impervious. White alkali has no injurious effect upon the physical condition of soils, but tends rather to produce a granular character which accompanies good tilth. The injurious effect of black alkali is largely caused by its corroding effect upon the plant roots; however, in the case of white alkali it is believed that the high concentration of salt outside the plant roots prevents transpiration or water absorption. If the concentration of the salt outside the plant roots is sufficiently great the osmotic pressure would cause the water to be drawn from the plant roots into the soil, thus causing the death of the plant.

Many samples of soil, shales, alkali incrustations, and drainage water collected in the district west of the Medicine Hat Sheet, and representing different soil conditions of southern Alberta, were analysed, but only sufficient data to represent the various soil conditions are brought together in Table XV. Although most of the samples were taken outside the Medicine Hat Sheet, they are undoubtedly representative of the alkali salts of southern Alberta.

The soils from some areas are relatively free from alkali salts, whereas in other areas there are considerable quantities present. In general the heavier types of soil contain the greater quantities of alkali salts. Most productive arid or semi-arid soils contain from .25 to .50 per cent. of water soluble salts. Soils containing more than .50 per cent. of total water soluble salts, exclusive of calcium sulphate, are justly viewed with suspicion, but soils containing large quantities of gypsum (Calcium sulphate), as do many of the soils of southern Alberta, will produce crops when they contain quantities of soluble salts which would be decidedly injurious provided there were no calcium sulphate present, since this salt ameliorates the toxic effect of the other alkali salts. The amounts of calcium sulphate shown in Table XV do not indicate the total amounts in these soils, since not more than one per cent. of calcium sulphate will be dissolved under the conditions of extraction used. Many of these soils contain at least several per cent. of total calcium sulphate. Even the clay loam represented by samples 215, 216 and 217 produces good crops under dry farming conditions. This soil, of course, would cause early trouble under irrigation.

TABLE XV.—WATER SOLUBLE OR "ALKALI" SALTS OF SOUTHERN ALBERTA.

Sample No.	LOCATION	Per cent.						P.P.M. Nitrate Nitrogen
		Na_2CO_3	Na Cl	Na_2SO_4	$Mg SO_4$	$Ca SO_4$	Total	
102	Clay loam surface 2-12-25	.02	......	......	.04	.07	.13	......
103	Clay loam subsurface 2-12-25	06	......	......	.04	.14	.24	......
104	Clay loam subsoil 2-12-25	.05	......	......	.20	.35	.60	......
215	Clay loam surface 24-15-23	.05	......	......	.05	.10	.20	......
216	Clay loam subsurface 24-15-23	.03	......	.07	.25	.42	.77	......
217	Clay loam subsoil 24-15 23	.03	......	2.01	.35	.35	2.74	......
136	Silt loam surface 23-10-22	.03	......	......	.04	.07	.14	......
137	Silt loam subsurface 23-10-22	.05	......	......	.05	.07	.17	......
138	Silt loam subsoil 23-10-22	.05	......	......	.05	.07	.17	......
206	Silt loam surface 1-17-24	.02	......	.18	.10	.14	.44	......
207	Silt loam subsurface 1-17-24	.02	......	......	trace	.03	.05	......
208	Silt loam subsoil 1-17-24	.02	......	.63	.30	.63	1.68	......
168	Loam surface 32-16-26	.02	......	......	trace	trace	.02	......
169	Loam subsurface 32-16-26	.04	......	......	.01	.01	.06	......
170	Loam subsoil 32-16-26	.03	......	.08	.05	.05	.21	......
270	Fine Sandy Loam surface 22-13-17	.03	......	......	trace	trace	.03	......
271	Fine Sandy Loam subsurface 22-13-17	.05	......	......	trace	.03	.08	......
272	Fine Sandy Loam subsoil 22-13-17	.03	......	......	.05	.77	.85	......
123	Surface alkali incrustation from lake S.W. ¼ 14-13-25	.26	1.10	48.77	22.50	.49	73.12	2.9
183	Surface alkali incrustation from lake S.W. ¼ 30-14-25	.18	.58	53.64	39.00	.77	91.17	......
143	Surface alkali incrustation from road, N.W. Corner, 22-10-24	.04	trace	5.49	1.15	.84	7.52	37.5
297	Surface soil around alkali depression	.64	......	4.10	.05	.04	4.83	43.0
285	Alkali incrustation salt seeping from shale	.10	trace	44.20	1.80	.87	46.97	25.00
279	Yellowish brown shale 20 ft. below surface	......	......	.57	.05	.26	.88	6.34
280	Reddish brown shale just above 297	.02	......	.36	trace	.07	.45	11.76
199	Sandstone several feet below surface 10-11-24	.02	......	......	trace	trace	.02	8.1
200	Sandy shale just below 199 19-11-24	.02	......	trace	.05	.02	.09	15.9
201	Sandy shale just below 200 10-11-24	.03	......	.31	.10	.04	.48	4.9
202	Shale	.03	......	trace	.05	.14	.22	3.9
203	Shale weathered from contact of drift 10-11-24	.06	......	.31	.08	.04	.49	5.4
204	Coal shale just below 203	.05	......	.66	.05	.04	.80	3.9
289	Drainage water	.02	trace	.02	.12	.13	.29	1.00
290	Drainage water	.01	trace	.86	.14	.22	1.23	112.00

(Salts extracted by using 50 gms. of soil and 250 cc. of water, shaking for three minutes, allowing to settle for twenty minutes, then filtering through Berkefeld filters.)

By observing the composition of some of the shale samples it is seen that they are at least one source of the salts found in the adjoining soils. That they are the main source of gypsum is unquestionable, since large selenite crystals were often encountered in the excavated shales. Distinct granules consisting largely of calcium sulphate were often encountered in the subsurface and subsoil samples. Some of the shales contain appreciable but not excessive amounts of nitrates. Drainage waters leaching from some of the shales were heavily charged with nitrates (see sample 290).

Whenever there is movement of water through these soils some salts likewise move about, and the more easily soluble ones tend to accumulate in the alkali spots, as may be seen from samples 123, 183, etc.

These soils in general have a high content of limestone and gypsum; thus the tendency is to retard the formation of black alkali. It is remarkable that these soils are almost devoid of black alkali, in fact, there is but a small amount present even in the alkali incrustations. The salts occurring in these soils belong to the white alkali group, and are less toxic than the brown or black alkali. The total carbonates (column one) are reported as sodium carbonate, but in fact the alkalinity is generally due to the bicarbonate. The only instances where any appreciable normal carbonates occur are in the salt incrustations, and often they are absent from these. The actual toxicity caused by black alkali will therefore be less than is indicated by the figures in column one.

No areas of typical brown alkali were encountered, but the shales do contain appreciable quantities of nitrates, as shown by samples 285, etc. Again considerable nitrates have been dissolved in the waters draining from the soil and shales as represented by sample 290. This sample contains nitrate equivalent to about 680 pounds of sodium nitrate per million pounds of water. Now, one million pounds of water is a very reasonable amount of drainage from an acre of heavily irrigated land, and there is enough nitrogen in this amount of water to produce 58 bushels of wheat. The total salts in solution in this sample are about 12,400 parts per million as against about 2,900 for sample 289.

In the soils of arid or semi-arid regions the greatest concentration of alkali is often found at about the depth of annual percolation of rains. The tendency of irrigation frequently is to produce a concentration near the surface. The water dissolves the salts, and when evaporation begins, especially if excessive amounts of water have been applied, the water moves upward carrying the salts and leaving them at the surface. This may ruin the land for ordinary crops. Seepage waters from canals and ditches sometimes pass through porous soil formations, which permit of large losses of water, and may cause a great deal of alkali trouble. The water may come to the surface at some spot or field below the ditch and bring up alkali gathered while passing through the soil, resulting in the spoiling of valuable land.

It should be mentioned that, in general, southern Alberta contains a smaller proportional amount of soil with excessive alkali salts than the great majority of districts of similar size in arid and semi-arid regions, but that with irrigation caution should be taken not to over-irrigate, otherwise certain sections will soon give trouble resulting from the accumulation of alkali salts. The best possible natural drainage should be utilized. It is more difficult to reclaim alkali lands than it is to prevent their formation. The lack of sufficient natural drainage has caused the formation of alkali flats and lakes (see Plate 3, Fig. 3). When the farmer applies irrigation water in excess he only facilitates the formation of alkali spots, unless he controls the amount used and provides for the drainage of any excess.

Since a great deal of land is injured or rendered useless by alkali its reclamation is an important problem. It is sometimes possible to produce crops on soils which contain considerable alkali by choosing alkali resistant crops, such as sweet clover or sugar beets, and by making an effort to prevent the accumulation of salts at the surface of the soil, as this is the point at which alkali salts do most of their injury. Deep plowing, just previous to seeding, and turning down the alkali which has accumulated near the surface will enable the seeds to germinate and the young plants to become established, and by proper tillage a mulch may be provided which checks evaporation and the rise of alkali until the crop is large enough to shade the ground. The removal of the excess salts from the soil, however, is the only remedy that will permanently reclaim alkali land. Leaching out the salts through underdrains or open ditches is usually the most practical and permanent remedy. This, of course, means the expense of a drainage system, and it may afterwards be necessary to flood the land several times before the excessive salts have been removd.

SUMMARY

The Medicine Hat Sheet is located in south-eastern Alberta and lies wholly within the treeless or bald prairie portion of the province. It consists of an area of 90 miles east and west, by 48 miles north and south, and its southern boundary is 48 miles north of the international boundary. The soil map for the area represents 120 townships, or 2,764,800 acres (see page 1).

The general elevation of the Medicine Hat Sheet is about 2400 to 2800 feet. The slope is generally towards the rivers which flow through the surveyed area, namely, the South Saskatchewan river and its tributaries. The topography is generally undulating or gently rolling, but there are some very considerable areas of rolling and even hilly land, especially in the eastern half of the Sheet (see pages 1 to 3).

The main towns or centers of population occur along the railroads, and the largest of these is Medicine Hat.

The transportation facilities for a large part of the Sheet are good, and for the whole area the transportation facilities are probably as good as the average for other districts of similar size in the southern half of Alberta.

Within the boundaries of the Medicine Hat Sheet are included some of the dryest districts of Alberta, and some areas of soil drifting. Some important irrigation districts are, in part, located within this Sheet (see pages 3 to 4).

The climate of the Medicine Hat Sheet (see page 4) is typical of the high plains region of Western Canada. It is characterized by long, bright moderately warm summer weather, and bright, cold, dry winter weather. The average annual precipitation is about 12 inches at Medciine Hat, and during the average season about 60 per cent. of the total precipitation falls during the growing season, May, June, July and August.

The average frost free period for 20 years, from 1902 to 1921, was 125 days at Medicine Hat, 106 days at Lethbridge, and 90 days at Edmonton. The yearly mean or average temperature is 43 degrees Fahrenheit. The average temperatures of the different seasons are as follows: Winter 16.3 degrees, spring 43.7 degrees, summer 66.5 degrees, fall, 45.6 degrees. The average maximum temperature for winter is about 26 degrees, whereas the average maximum for summer is about 80 degrees and the average minimum about 53 degrees. During the summer the mercury seldom reaches the 100 mark, and very

rarely goes down to freezing. This season has long warm days of bright sunshine, which permit of rapid growth of crops.

It is estimated that about one half million acres within this area are at present cultivated (see page 12).

The wheat crop is the chief source of income within the area, as mixed farming is practised to but a limited extent. During the 6-year period, 1915 to 1920, about 66 per cent. of the crops consisted of wheat and about 25 per cent. of oats, these two crops constituting over 90 per cent. of the total (see pages 10, 11).

For the 13-year period, 1910 to 1922, the average yield of spring wheat was 12.7 bushels, and the average yield of oats was 24.2 bushels (see Table V).

The yields obtained under dry farming vary with the rainfall. In general, the seasons of low rainfall are the seasons of low yields, and the seasons of high rainfall are the seasons of high yields, although certain factors such as seasonal distribution, etc., prevent perfect agreement in this respect (see Figures 2 and 3, page 14). As a rule a unit of rainfall is found to be less efficient in producing crops during the extremely dry years than during the wetter years; for example, the dry years produced less than one-half bushel of wheat for each inch of rainfall, whereas the wetter years produced as much as two and one-half bushels for each inch of rainfall (see page 17). As an average of 18 years each inch of rainfall has produced about 1.1 bushels of wheat.

It is shown that with the present system of farming in the Medicine Hat Sheet it requires about 1,700 pounds of water to produce one pound of dry matter in the form of the wheat crop, and it is suggested that better attention to the fallow and rotation practices should enable the farmer to obtain larger yields from the water or rainfall available (see page 20).

Many wheat farmers have moved away from the Medicine Hat district, and it is evident that the unmodified grain farming practice cannot be depended upon as a permanent system of agriculture. It is suggested that more live stock and forage crops would materially lessen the farming hazard, and that some of the land should be turned back to ranching (see page 19).

The soils of the Macleod Sheet (see soil map, also page 19) consist chiefly of glacial drift derived largely from the materials weathered from the underlying shale and sandstone formations. Over two-thirds of the soils of this Sheet are medium and heavy in texture, and almost all of this, or about two-thirds of the area, consists of loam and silt loam (see Table VIII). The lighter types, fine sand, and fine sandy loam, constitute about 17 per cent. of the total, while the mixed areas, eroded areas, and river bottoms occupy about 12 per cent. It is rather fortunate that such a large proportion of this sheet consists of soils of intermediate texture, since such soils absorb and carry more moisture from one season to another than do the lighter soils, and are more readily worked than the very heavy soils.

The Medicine Hat Sheet soils are usually fertile and well supplied with plant food (see Tables IX, X and XI), although as a rule they do not contain as much organic matter and nitrogen as the soils of some other parts of the province, and continent (see Table XII). The lack of nitrogen is more apt to reduce crop production than the lack of any other plant food (see Table XI), and in this connection the importance of growing legumes such as alfalfa and sweet clover, in order to add nitrogen to the soil, is discussed, with special reference to its importance in irrigation farming (see pages 36, 37). In no instances are the soils sour or deficient in limestone. The sands are fertile as compared with most sand soils, but they will not hold up under cropping as well as the other soil types. Tables IX, X and XI show that the essential plant foods are less plentiful in the fine sand and in the fine sandy loam than in the other soil types.

Experiments quoted (see page 37) show that the straight grain farming system is tending to reduce the soil's supply of readily decomposable organic matter, and it is pointed out that rotations including sod-forming crops, such as Brome grass, and summerfallow substitutes, such as corn, would be more conservative. Since a soil's crop producing power depends, in large measure, upon the decomposition of organic matter in the soil, it is important that a supply of readily decomposable organic matter should be maintained. Organic matter also increases water holding capacity, and if fresh or fibrous, helps to prevent soil drifting.

Soil drifting is discussed in the body of the report (see page 38). It is not as serious a problem in the Medicine Hat Sheet as it is in the areas to the west. Nevertheless it is a menace and does considerable damage in seasons of high winds. All soil types drift somewhat during seasons of high winds, when not protected by crop growth, although the sands undoubtedly drift earlier after breaking than the other soil types. Methods of control are briefly presented, special emphasis being placed upon the need of maintaining fibre in the soil.

The advantages of a rotation of crops as compared to the one crop grain farming system are discussed (see page 39), and the importance of including grass and legume crops at intervals in the rotation, in order to maintain the fibre and nitrogen content of the soils, is stressed.

In the discussion on summerfallow (see page 40) figures are given which show that a single season's moisture supply is not always sufficient to produce a crop, and that the summerfallows (or summerfallow substitutes, such as corn) are absolutely necessary. It is pointed out, however, that it should be possible to produce greater yields from the rainfall available than are now obtained. Furthermore, it is shown that crops following a fallow are benefited by the soluble plant food which accumulates in fallow soil to a much greater extent than in cropped soil, as well as by the accumulated moisture.

There are approximately 390,000 acres classed as irrigable land within the Medicine Hat Sheet (see page 42). This is about one acre out of seven. As yet, however, only a very small proportion of this irrigable land is actually being irrigated. The soils of the Medicine Hat Sheet are, in general, well adapted to irrigation, since most of them are intermediate in texture, and relatively free from boulders. It is noted that the soils of this sheet are almost devoid of black alkali; the salts occurring in these soils belong to the white alkali group, and are less toxic than the brown or black alkali salts. Furthermore, most of the soils have a high content of limestone and gypsum, which tend to retard the formation of black alkali (see page 51).

Appendix I (see page 51) contains certain details which it seemed advisable to omit from the body of the report, including notes on soil classification and characteristics of different classes of soil.

In Appendix II (see page 65) will be found a discussion of the geology of the area by Dr. J. A. Allan, Professor of Geology in the University of Alberta.

APPENDIX I

SOIL SURVEY METHODS

The soil survey was generally carried out by driving along the roads and stopping frequently to take notes regarding class of soil and subsoil, topography, stones, suitability of soil for cultivation, etc. The roads running north and south are one mile apart, and the roads running east and west are two miles apart. In most cases the land was traversed at intervals of one mile. In some cases roads had not been opened up, and it was then necessary to drive across the prairie. The location was usually obtained from corner posts and speedometer readings. In some cases one soil class changes abruptly to another, and in these cases there is no doubt regarding the point at which the boundary line should be placed, but more often one soil class merges gradually into another, and in these cases the point at which the boundary line is placed must be chosen arbitrarily. Then, of course, it is necessary to draw in the boundaries arbitrarily between roads, or between points of observation. After the boundaries had been established in this way the areas were sampled systematically and the samples were sent into the laboratory for analysis.

Most of the field notes were recorded on township maps obtained from the Topographical Surveys Branch of the Dominion Department of the Interior. The township map is made with a scale of two inches to the mile. Further notes were recorded in convenient field note books.

In a survey carried out in this manner, and recorded finally on a map with a scale of three miles to the inch, minor areas cannot be outlined, and boundaries cannot always be very accurately established. Hence, although the extensive soil types are outlined fairly accurately, the map should not be depended upon, without further inspection, for the purchase or sale of individual quarter sections. Many factors influence land value, but the maps should prove very useful, in a general way, as a guide for the purchase or sale of land.

SOIL CLASSES

All soils are composed of particles of different sizes, which are designated by various grades. Generally only the finer soil particles (less than 2 mm. in diameter) are analyzed and used in classification. In order to confirm our field classification we determine the following grades:—

		Number of Soil Particles per inch.
1. Fine Gravel	2— 1 mm.	12— 25
2. Coarse Sand	1— .5 mm.	25— 50
3. Medium Sand	.5— .25 mm.	50— 100
4. Fine Sand	.25— .1 mm.	100— 250
5. Very Fine Sand	.1— .05 mm.	250— 500
6. Silt	.05—.005 mm.	500—5000
7. Clay	less than .005 mm.	more than 5000

A better idea of the diameter of the various grades may be obtained by comparing the mm. scale with the inch scale.

We are using the same system of soil classification as that used by the Dominion Department of the Interior. It has been adopted from the systematic classification used by the United States Bureau of Soils. It is briefly outlined below.

1. SANDS contain less than 20% of clay and silt, and 80% or more of sand.
   - (a) Coarse Sand—more than 25% fine gravel and coarse sand, and less than 50% of any other grade of sand.
   - (b) Medium Sand (usually designated sand)—more than 25% fine gravel, coarse and medium sand; and less than 50% fine and very fine sand.
   - (c) Fine Sand—more than 50% of fine and very fine sand; less than 50% of very fine sand.
   - (d) Very Fine Sand—more than 50% very fine sand.
2. SANDY LOAMS contain 20-50% clay and silt, with less than 20% of clay (50-80% sand).
   - (a) Sandy Loam—more than 25% gravel, coarse and medium sand.
   - (b) Fine Sandy Loam—more than 50% fine sand and less than 25% gravel, coarse and medium sand.
   - (c) Very Fine Sandy Loam—more than 50% very fine sand and less than 25% gravel, coarse and medium sand.
   - (d) Sandy Clay—less than 20% silt (very seldom used).
3. LOAMS (other than sandy loams) — Soils containing more than 50% clay and silt.
   - (a) Loam—contains less than 20% clay, less than 50% silt, less than 50% gravel and sand.

(b) Silt Loam—less than 20% clay, more than 50% silt.

(c) Clay Loam—20-30% clay, less than 50% silt.

(d) Silty Clay Loam—20-30% clay, more than 50% silt (seldom used).

4. CLAY—more than 30% clay.

Sand particles vary in size from 1/25 to 1/500 of an inch. They feel rough and gritty, and will not stick together either when wet or dry. They consist chiefly of the more resistant rock particles such as quartz.

Silt particles vary in size from 1/500 to 1/5000 of an inch and are midway between sand and clay. When wet they feel velvety, but lack both the roughness of sand and the stickiness of clay.

Clay particles are the smallest of individual soil grains and have a diameter of less than 1/5000 of an inch. Some of them are so small that it is impossible to see them with a powerful microscope. They settle out of water so slowly that the solution may be turbid for months. When wet they are greasy and sticky, and upon drying shrink and become hard.

Sands.—Sand soils consist chiefly of the more resistant rock particles which have withstood the centuries of weathering. The particles were formed originally by the disintegration of native country rocks. This weathered material may remain in place, but usually it is subjected to assorting and placing by water and winds, and generally occupies positions relative to water areas and prevailing winds.

From the preceding classification it may be seen that at least 80 per cent. of the particles of sand soils have diameters greater than .05 mm. (1/500 of an inch). Since sands do not contain over 20 per cent. of the finer particles they are always easily worked. Their water holding capacity is small, and, although they absorb a certain amount of water readily, they retain it poorly, and are easily leached. They can be worked when either wetter or drier than any other kind of soil, and may be kept in good tilth with les scultivation than is required for other kinds of soil. They are always warm and early but are frequently too loose and dry to form an ideal seed bed.

The finer sands usually contain more silt than the coarser sands, and this improves their physical properties. When sand areas are subjected to the continued action of winds the finer material is carried farther to leeward than the coarser particles. Thus in typical sand areas we frequently find the coarser sand piled up in dunes, while to the leeward there is a gradual transition into the finer sands and ultimately into the sandy loams and loams.

Sandy soils are generally found to be relatively infertile. This low production power is explained by the fact that initially the sands, as a rule, are high in silica or quartz, and low in plant food, and that, in climates with heavy rainfall they are greatly leached. However, with the materials which have contributed to the formation of sand areas in Alberta, and under the climatic conditions of the western Canadian prairies, we find that the sands are comparatively fertile. (See discussion of sand areas.)

Owing to their loose open nature, and to their low initial content of organic matter, sands begin to blow sooner after breaking than the heavier soils. The greatest problems in the management of sands are the maintenance of organic matter and plant foods, and the control of moisture. The maintenance of root fibre and organic matter automatically tends to lessen drifting and conserve moisture.

These properties of sands adapt them to truck gardening, to crops such as potatoes and fruits, and to certain early field crops such as fall rye and sweet clover. Of all our grain crops winter rye does best on sands, since it becomes established in the fall, and starts growth very early in the spring, and can thus more completely utilize the annual precipitation. It likewise tends to prevent winter drifting of soil. In very wet years our sands will respond with enormous crops, but they are not nearly as durable as the heavier soils.

Sandy Loams, Loams, Silt Loams, Clay Loams.—Between sands and clays there is a group of intermediate or loam soils. These various loams are designed by property names, and are known as sandy loams, loams, silt loams, and clay loams. The lightest sandy loam does not contain over 80 per cent. of sand, and the heaviest clay loam does not contain over 30 per cent. of clay. When the proportion of sand is great the soil possesses properties closely related to those of sands, and when the proportion of clay is great the soil is more closely related to the clays. When the proportions of sand, silt, and clay are such as to impart no predominating property of one constituent, the soil is just called loam.

The sandy loams are adapted to the early crops, but are better suited to a greater variety of crops than the sands, because of their greater water-holding capacity and fertility. The lōams are often spoken of as the all-round soils, and are, as a rule, adapted to a greater variety of crops than any other class of soils. The silt loams and clay loams require more careful management than the lighter loams, in order to maintain good tilth, but they are fertile, durable, and usually well adapted to cereals, grasses, legumes, and other common farm crops.

Clays.—Soils containing large proportions of very fine particles are designated clays. All clays contain at least 30 per cent. of soil particles with a diameter of less than .005 mm. (one-five-thousandth of an inch). Generally a large percentage of the particles of clay soils is silt. These soils owe their origin, generally, to the finer particles which have settled out of bodies of quiet water, the material having first been carried into settling basins by streams. Many of the glacial boulder clay areas have been subjected to a lesser extent to separation and settling, and consequently contain coarser material and stones mixed with the clay.

We often hear the terms "gumbo,,' "buckshot", "adobe" used in reference to clay soils. Gumbo is an exceptionally heavy kind of clay, usually dark brown or black in color, occurring both on river bottoms and upland flats. It is more sticky and bakes more readily than any other kind of soil. Buckshot is a certain kind of calcarous clay, which, upon drying, forms small granules rather than large clods, thus producing a good natural tilth. Adobe soils are heavy clay soils occurring chiefly in the arid south-western states. They consist of material, part of which has been placed by water, and part blown in by wind.

Clays are just the opposite of sands in physical properties, and the characteristic properties of clays are due to their extremely fine texture. Sands are loose, open, easily worked, early, and less productive, whereas clays are fine, compact, sticky, hard to work and late. Clays absorb water slowly and give it up slowly. Upon drying clays shrink, crack and become hard and cloddy. Such soils are often hard on plants, as well as hard to till, as they shrink at times until they break the plant roots. The greatest problem in connection with clay soils is that of cultivation.. When worked too wet the particles run together, and, with subsequent drying hard clods are formed. At a certain moisture content between extreme wet and dry soil, clays pulverize and form a good seed bed. They should never be plowed when too wet. One such plowing may practically ruin the tilth for a number of years. Clays are often deficient in organic matter, and one of the most effective methods of improving poor clay soils is to incorporate organic matter with the soil, either by addition of manure, or by growing and plowing down legumes. When properly handled clays usually produce good crops, since they are generally well supplied with mineral constituents needed for plant food.

Clay soils are adapted to many of the grasses, cereals, and legumes, and because of our climatic and market conditions, some of the best crops for our heavier soils are western rye grass, brome grass, wheat, oats, and sweet clover. Under irrigation the choice of crops might be extended, and might include timothy, red top, alfalfa, and roots. Sweet clover and alfalfa are among the most promising crops for our heavier soils, since they readily penetrate the heavy subsoil, making channels for water and air. Furthermore they add nitrogen as well as organic matter to the soil.

APPENDIX II.

THE RELATION OF THE GEOLOGY TO THE SOILS IN THE MEDICINE HAT SHEET

BY JOHN A. ALLAN.*

Soil may be regarded as unconsolidated rock. Most soils have been derived from the decomposition and disintegration of older rocks. There is usually a close relationship between the soils in an area and the geology in or close to that area.

Much of the surface of the southern half of Alberta east of the Rocky Mountains is mantled with unconsolidated deposits of Pleistocene and Recent ages. The soils of Pleistocene age are chiefly of glacial origin, and the younger Recent deposits have been derived quite largely from the older glacial deposits, or from the rocks immediately underlying the soil. This condition of soil origin occurs throughout almost all of the Medicine Hat sheet.

Only a short time has been spent in the field examining the surface deposits in this map-area, so that the following notes must not be regarded as a complete geological report on the surficial deposits in the Medicine Hat sheet. An attempt will be made to point out some of the more prominent geological features responsible for the distribution of several of the soil types shown on the map accompanying this report. More detailed observation would have to be carried out in the field before all soil types in every part of the area mapped could be correctly interpreted. A correct interpretation of the soil occurrences in every case required a knowledge of the sub-surface geology and structure of the rocks. This detailed information is not yet available in some parts of the Medicine Hat sheet, because there are very few rock exposures except along the larger valleys that are deeply incised into the surrounding plain.

ORIGIN OF SURFICIAL DEPOSITS

The soil differs from underlying deposits upon which it is developed in that weathering agents have changed its original texture, color, and composition. In some soils the accumu-

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lation of organic material, both vegetable and animal, has caused the soils, particularly the surface soils, to assume a dark color. In most cases surface leaching has deprived the soils of certain original minerals, and often the mineral content in the subsoils has been changed. In many of the soils in the Medicine Hat sheet the calcareous content has been reduced by processes of weathering and an increase of the lime content occurs in the subsoils. On the other hand, if the unconsolidated deposits contain certain soluble minerals these are brought to the surface in the ground waters and in such cases the soils will be richer in those minerals than the subsoils. All these conditions have to be considered in explaining the origin of the soil types that occur in the map-area.

The unconsolidated deposits in the Medicine Hat sheet can be classified into four types:

(1) Glacial moraine, unsorted.
(2) Resorted glacial deposits.
(3) Transported deposits of alluvial, laccustrine, dune and eolian.
(4) Residual deposits.

The glacial deposits consist of *till* or *boulder clay* in the form of moraines that have been left by the ice-sheet that covered the area. These deposits are unstratified, and consist of an unsorted mixture of clay, sand and gravel. Ground moraine occurs in almost all parts of the area. It varies in thickness, and in some places is almost missing, having been removed by later erosion. The rolling and hilly country in the north half of the map-area is formed in part of the boulder clay.

Glacial drift in the form of terminal or lateral moraines occurs in this area. These deposits usually occur as ridges, and have been formed by deposition of material from the glaciers along the margin. The material is similar to that in ground moraine, but a thicker deposit in the form of a ridge marks the position where the front of the ice halted for a time. The high land in Little Rolling Hills in the north-west corner of the sheet, and extending southwards to Oldman river, has been formed at least in part from a morainal ridge. There are other morainal ridges of a similar origin along the north boundary of the map in ranges 7, 8 and 9, and west of Saskatchewan river.

The second type of soil is that resulting from *glacial drift* that has been *resorted* and deposited along old glacial drainage courses, or in ponds and lakes close to or near the front of the retreating ice sheet. In some cases *outwash plains* have been formed from deposits carried out by streams coming from under the ice sheet around its margin. This is one of the most common types of deposits in this area.

The third type of surface material includes the *transported deposits.* The transporting agents have been running water and wind. Along the present river courses such as the South Saskatchewan and Oldman rivers alluvial deposits of silt and gravel occur as flood plains and terraces. Most extensive deposits of this type occur north of Medicine Hat in the Saskatchewan valley, and near the junction of the Bow and Oldman rivers. Similar deposits occur along old drainage courses that were formerly occupied by running water. Remnants of these deposits occur along Bullshead and Sevenpersons creeks south of Medicine Hat, and along many other ravines in the south-east corner of the map. There is a very marked band of mixed soil shown on the map, chiefly in range 15, and extending from Oldman river to Bow river. This soil consists largely of alluvial material formed along an old drainage course.

This type of deposit is also found around the margins of lakes and swamps, and in basins that were originally lakes. Many examples of this class occur in this area. In the north-east corner of the map this type occurs around Many Island lake, and as far west as Chappice lake; along the depression occupied in part by Red Deer lake and in the vicinity of Schuler similar deposits are widely distributed in the north-east quarter of the sheet, particularly from Suffield eastward. There are a number of lake basins south and west of Alderson, and along the depression now followed by the Canadian Pacific Railway irrigation canal and Twelve Mile creek. There are also lake deposits around Lake Newell, which is the largest lake in this area, although this lake is of glacial origin and has been formed on the glacial moraine. Lake deposits also occur in this area along Forty Mile coulee at the southern boundary of the map and south of Burdett and Bow Island.

The fourth type of soil includes the *residual deposits* that have been formed by erosion processes from the underlying strata. Soils formed in this way will have a composition somewhat similar to the composition of the underlying rock from which they have been formed. For example, certain areas of sandy loam indicate the occurrence of clayey sandstone below, while silt loam and clay loam suggest the presence of shale formation in the underlying rocks. In the Medicine Hat sheet residual soils are not common because erosion is going on slowly today, and residual soils that have been formed in the past have been extensively reworked by surface agents. Small areas of residual soil occur in various parts of the Medicine Hat sheet. The most extensive areas of residual soil that were observed occur in the south-east corner of the sheet, along the base of the Cypress hills on the north slope. Much of the soil type mapped as loam on this part of the sheet has been formed in this way, although where the surface is rolling there have been certain constituents removed by surface leaching so that the composition of the soil is not identical with the composition of the underlying rock.

All four types of soil are represented in this map-area, but in order of importance the types are two, three, one, and four.

GLACIAL HISTORY OF THE MEDICINE HAT SHEET.

The study of the surface deposits and the present phsyiography of the Medicine Hat sheet involves the glacial history of this part of Alberta. The glacial history of this sheet, insofar as it is related to soil types, is so intimately connected with the glaciology over a large part of Southern Alberta that it is in order to include a few general notes on the subject.

During the late Tertiary time and long before the southern advance of the continental ice sheet from the west side of Hudson Bay there was a pronounced topography in Southern Alberta. The physical features became more pronounced by erosion as the Glacial Period approached. The erosional features in this part of Alberta were formed largely through the uplift of the Rocky Mountains. It was toward the close of the Cretaceous period in the Mesozoic era that the initial uplift of the Rocky Mountains occurred. As this uplift continued, drainage channels were formed on the eastern slope. Ultimately a pronounced system of drainage was developed, with major streams having a general easterly direction. This pre-glacial drainage down the east slope of the Canadian

Rocky Mountains is today represented in general by such rivers as the Oldman, Bow, North Saskatchewan, Athabasca, Peace and many other smaller rivers.

In the Medicine Hat sheet both the Oldman and Bow rivers and the South Saskatchewan beyond their junction are of pre-glacial date. The present position of these river valleys is not identical with the pre-glacial valleys, but in general it is a fact that approximately the same general course was followed by these pre-glacial rivers. There is some indication that possibly the pre-glacial South Saskatchewan flowed eastward from Medicine Hat, instead of turning northward, as at the present time.

It is not necessary in this report to discuss details regarding pre-glacial topography. It is apparent, however, that the general surface of this part of Alberta at the close of the Tertiary was a rolling plain, deeply incised with many valleys. The elevation of this plain was considerably above the present elevation—at least as high as the top of the Cypress Hills. When the glacier advanced this part of the Province was covered with what is known as the Keewatin ice sheet, which originated in the snow fields west of Hudson Bay. This ice sheet advanced beyond the southern boundary of Alberta. The advancing ice sheet brought with it Precambrian boulders and finer rock debris from the north-east, but the largest part of the load of the ice consisted of rock debris from the younger Cretaceous and Tertiary formations over which the ice passed. The original elevation of the plain in the Medicine Hat sheet was lowered by erosion from the ice sheet. There is no way of determining the exact amount of material that has been removed by erosion over all parts of Southern Alberta, but it is a recognized fact that the glaciers at no time covered the Cypress hills. On this evidence it is fair to assume that the greater part of the Medicine Hat sheet has had at least five hundred feet removed by ice erosion, and possibly nearly one thousand feet in some parts of this area.

With a more moderate climate the ice sheet melted and the enclosed rock debris was left as glacial drift. It is important to bear in mind that this drift was made up of heterogeneous rock debris consisting in large part of silica-, alumina-, potash- and magnesia-rich debris from the Precambrian rocks to the north-east, and silica-, lime-, and alumina-rich sand and clay from the Cretaceous and younger rocks at the surface north-east of the Medicine Hat sheet, which were ground up by the advancing ice sheet. There is very little debris in this map-area that has been derived from the Rocky Mountains, and it does not seem probable that this mountain debris has had any important effect on the composition of the soils in the Medicine Hat sheet.

Glacial erosion is always caused by the forward movement of the ice. During the retreat of the ice sheet the ice does not move backward, but the front of the ice sheet is melted more rapidly than the forward movement of the ice.

The front of any ice sheet is irregular and lobate in outline; tongues of ice project further forward than other parts of the ice mass. This applies to the Pleistocene ice sheets as well as to modern glaciers. There is evidence in the Medicine Hat sheet that a lobe of ice extended from the northern boundary of the map-area several miles southward—possibly almost as far as the present position of the South Saskatchewan river. From the front of this lobe a broad outwash plain was developed. This outwash plain is indicated on the map by the soil types south of the South Saskatchewan river between Sevenpersons creek on the east and Burdett and Ronalane on the west. These soils consist essentially of silt loam and loam. North of the South Saskatchewan river the country is more rolling, thus indicating that the surface material has the character of the ground moraine left as the ice front moved northwards, but this moraine has been worked over to some extent in post-glacial time.

On both the east and west sides of this lobe of ice there were drainage courses across the Medicine Hat sheet carrying the water southward from the retreating ice sheet. This eastern drainage course extends from the northern boundary of the sheet in Ranges 5 and possibly 6, along the present general course of the Saskatchwan river to Medicine Hat, and in a south and south-westerly direction to include the Bullhead creek and Sevenpersons creek.

The fine sandy loam and mixed types of soil have been formed in part along this old drainage. On the west side of the lobe there is evidence that there was also drainage following a course subparallel to the ice front. This drainage is today represented by Forty Mile coulee, and extends north north-westerly to include a part of the Bow river in the vicinity of Ronalane and Terrace, and then north-westerly along Twelve Mile creek to the northern boundary of the map. Here again we find a prevalence of fine sandy loam and some mixed soil areas. The most marked old drainage course is represented by a narrow band of mixed soils extending from Oldman river northward to Bow river, chiefly in range 15. This course, undoubtedly, was formed when the front of the ice lobe occupied the area immediately east. It is quite possible that this drainage course extends north of Bow river on the west side of Little Rolling hills, which are morainal in character, to Lake Newell.

It seems quite possible that by post-glacial erosion the South Saskatchewan valley between the Grand Forks and Medicine Hat was originally deepened while the ice front stood a short distance north of the present valley. There is also evidence of old drainage courses of glacial age extending in an east-west direction from Suffield across to the Saskatchewan river, and possibly continuing eastward to include the mixed soil in the vicinity of Many Island lake on the east boundary of the Medicine Hat sheet.

Post-glacial erosion has deepened many of the depressions that originated during the glacial retreat. Erosion has exposed the underlying rock in the main drainage courses, and also in tributary valleys. The effect of post-glacial erosion is clearly shown on the map in the south-east corner where the bedrock is exposed on numerous tributaries on the north and west slopes of Cypress hills. The South Saskatchewan valley from Medicine Hat to the northern boundary of the sheet is of glacial and post-glacial origin. As stated above, there is evidence that originally the drainage along this part was in a southerly direction, but due to a damming of the outlets and the formation in some cases of glacial lakes, the drainage at a later time followed this course, such as is seen in the South Saskatchewan river from Medicine Hat northwards.

In Bulletin No. 11—"Soil Survey of the Macleod Sheet" —p. 71, it was pointed out that there was evidence of at least two ice advances in that part of Alberta. In that sheet there are two layers of glacial deposits left by two ice retreats, and separated by a well defined series of beds formed during an interglacial period. The uppermost deposits of glacial drift belong to the Wisconsin stage and the older deposits to a pre-Wisconsin stage, possibly Kansan or even Nebraskan in age. It was also pointed out that the deposits left by retreating ice sheets in two different ages has been a contributory factor to the heterogeneity of the drift in that sheet. There is no doubt that the heterogeneous character of the soils in at least the western half of the Medicine Hat sheet has been caused by similar phenomena, although no definite evidence of more than one ice retreat has yet been noted in the Medicine Hat sheet.

SUBSURFACE GEOLOGY.

The rock formations underlying almost the whole of the Medicine Hat sheet belong to the uppermost *Belly River* and the younger *Bearpaw* formations. Both of these formations are of Upper Cretaceous age. The *Belly River* strata consist of clayey sandstones, sandy shales and in some members less indurated shales that are almost clays. The underlying *Bearpaw* formations consist essentially of marine shales, usually dark grey in color. There is a marked lime content in the strata belonging particularly to the *Belly River* age. The calcium content in the soil type in the Medicine Hat sheet has been derived very largely from the distintegrated Cretaceous rocks. Dr. Wyatt has noted that the calcium content is usually lowest in the surface soils and highest in the subsoils. In most cases this change is undoubtedly due to leaching of the lime from the surface downwards. In other cases it may be due to the proximity of the soil to the underlying rock. This would be the case where the soils are of residual origin.

On account of the widespread distribution of the unconsolidated deposits in the Medicine Hat sheet and the scarcity of rock outcrops except along the deeper valleys, it has not yet been possible to work out in detail the entire distribution of these two rock formatins. In general it may be said that west of Range 5 the uppermost rock belongs to the *Belly River* with possibly an occasional residual of *Bearpaw* capping the higher elevations. The *Bearpaw* strata, on the other hand, underlie a considerable portion of the map-area east of Range 5. The *Bearpaw* is very well developed from Walsh and Irvine on the main line of the Canadian Pacific Railway south to the boundary of the map. It is probable that these rocks also underlie the soils at least as far north as Many Island lake. The soil types from the south boundary of the map area at least as far north as Township 15 are to a large extent residual in character. Heterogeneous material in these soils has been transported northwards from the top of Cypress hills.

The Edmonton formation, which is uppermost Cretaceous, the Paskapoo of lower Tertiary, and a younger conglomerate formation also of Tertiary age have a different composition both mineralogically and chemically from the *Bearpaw* and *Belly River strata.* Cypress hills form a residual of erosion, and are capped by a bed of conglomerate ranging from fifty to five hundred feet in thickness. This conglomerate is of Tertiary age, and possibly belongs to the Oligocene. It consists largely of quartzite pebbles and small boulders cemented together with sand and calcareous clay. These hard boulders are found distributed over the surface almost as far north as Walsh and as far westward as Bullhead creek.

At the north-west corner of the map the *Bearpaw* shales occur close to Lake Newell and possibly underlie this portion of the map-area. The small patches of clay and clay loam north of Alderson have possibly been influenced by the occurrence of these marine shales that either underlie this area or occur very close to the northern boundary of the Medicine Hat sheet.

CONCLUSIONS.

This brief discourse of some of the more salient geological factors contributing to soil formation in this map area must not be regarded as a detailed description of all factors. As stated at the beginning, geological data for the whole area have not been obtained. It is hoped, however, that these few geological notes will emphasize the important influence that the underlying consolidated rock formation and the unconsolidated glacial and alluvial deposits have on the distribution of soils types.

WATER SUPPLY.

The scarcity of lakes and small streams in the Medicine Hat sheet and the presence of irrigation ditches in the western part of the map-area suggest that there is a deficiency of surface water, either due to a rapid run-off or to porous surface soils or to the lack of precipitation. The problem of underground water supply in this map-area is sufficiently important to require detailed consideration. Unfortunately, detailed information on the water supply in the Medicine Hat sheet is lacking so that only a few notes can be given in this report. The only published data on the artesian water supply in this part of Alberta have been recorded by Dr. D. B. Dowling in various publications of the Federal Geological Survey.*

*Dowling, D. B.—Geol. Surv., Can., Summary Reports 1915, p. 104; 1917, p. 1C; 1922, p. 104B; Memoir 93, 1917, p. 122.

Much valuable and exact geological data on this problem have been recorded by Dr. Dowling. He has proven the occurrence of a water-bearing sandstone in southern Alberta, has tabulated all well records up to 1922, and has compiled maps and models which show the depth at which the water-bearing formation occurs in southern Alberta, principally from the boundary line to Township 14. The reader is recommended to consult these publications for fuller details on this problem.

The three essential factors for an artesian water reserve are a porous rock, such as a sandstone, which will act as a container in absorbing the water; an impervious roof, such as shale, to prevent the water from escaping to the surface as seepage; and an impervious floor, also shale, which will prevent the water from becoming dissipated in the lower formations.

These three factors are all present in southern Alberta, and especially in the southwestern part of the Medicine Hat sheet.

The *Milk River sandstone* has been proven by a number of drilled wells to be the principal artesian water-bearing rock. This formation occurs at the base of the *Belly River series* of rocks, and is overlain and underlain by impervious shale formations. This sandstone is believed to underlie the whole of the Medicine Hat map-area. It comes to the surface in the Cypress hills near the inter-provincial boundary south of Medicine Hat.

On account of the porous character of this sandstone, the water enters the formation along the outcrop and flows down the strata towards those parts where it occurs at the lowest elevation with reference to sea-level datum. Water will be found in almost all parts of this formation, except where the pores in the sandstone have been filled with natural gas, as in the Medicine Hat, Bow Island and Burdett gas fields. In many parts the pressure will be sufficient to force the water to the surface and form an artesian well.

The depth of the top of the Milk River sandstone, which contains the water-bearing starta, has been proven in a number of wells drilled for gas and water in the Medicine Hat sheet and recorded by Dr. Dowling.[1]

[1]Geol. Surv., Can., Sum. Rept., 1922, p. 115B.

Tp.	Rg.	No. of wells	Depth to gas- or water-bearing formation	Product.[1]
14	1	1	1,530	G.
12	5	6	898-1,098	G.
12	6	2	914-1,029	G.
13	6	1	967	G.
9	9	2	740- 785	W.
9	9	1	670	W.G.
14	9	1	885	G.
9	10	2	750- 750	W.
9	10	2	758-[2] 946	W.G.
10	10	1	869	W.
10	10	1	827	W.G.
15	10	1	1,040	G.
9	11	5	650- 746	W.
10	11	4	640- 822	W.
10	11	1	735	W.G.
11	11	9	410- 860	W.
9	12	10	620- 670	W.
9	12	1	620	W.G.
10	12	6	620- 740	W.
11	12	2	585- 627	W.
13	12	1	775	W.
9	13	5	640- 690	W.
10	14	1	660	W.
9	15	1	680	W.
9	15	1	666	W.G.
10	15	1	......	W.
19	15	1	820	G.

[1]G represents gas and W represents artesian water.
[2]Government well No. 2.

This table indicates that the structure is dipping gently to the north-east, and that the top of the *Milk River sandstone*, which contains the water-bearing horizons, occurs at depths ranging from 1,900 feet to 2,100 feet above sea-level in Township 9; between 1,800 and 2,000 feet above sea-level in Township 10; and at greater depths to the north and north-east of the Medicine Hat sheet. This means that over the greater part of the Medicine Hat sheet the only proven artesian water-bearing sandstone occurs at much too great a depth below the surface to be tapped by drilling, as the cost would be excessive.

Analyses of six samples of water from artesian wells in southern Alberta were made by the Dominion Chemist, Dr. F. T. Shutt, and quoted by Dr. Dowling in the report mentioned above. Three of these analyses are given below. One of the samples of water comes from the Medicine Hat sheet and the other two from wells close to the western edge of this map-area. Sample No. 1 is from Well No. 2 drilled by the Dominion Government in Section 19, Township 9, Range 10. Sample N. 2 is from a well in Section 32, Township 9, Range 16, at Taber. Sample No. 3 is from a well about eight miles south of Retlaw in Section 28, Township 11, Range 17.

The analyses of these water samples are as follows:

	No. 1	No. 2	No. 3
	p.p.m.	p.p.m.	p.p.m.
Total solids at 105°C	1520.0	2692.0	6080.0
Loss on ignition	240.0	130.0	400.0
Solids after ignition	1280.0	2560.0	5680.0
Lime (CaO)	Fr. or tr.	Free or tr.	Traces
Magnesia (MgO)	"	"	"
Soda (Na_2O)	600.0	1400.0	2400.0
Sulphuric acid (SO_3)	10.0	10.0	20.0
Chlorine (Cl)	250.0	760.0	3160.0
Carbonic acid (CO_2)	470.0	480.0	390.0
Reaction	alkaline	alkaline	alkaline
Hypothetical Combination.	grains per gallon	grains per gallon	grains per gallon
Sodium sulphate (Na_2SO_4)	?	?	?
Sodium carbonate ($NaCO_3$)	78.4	80.5	63.0
Sodium chloride (NaCl)	28.0	88.2	317.8

Dr. Shutt describes these waters as follows: "The water from Government well No. 2 is slightly more saline than the water just discussed (Beaver well), the total saline content being 1,500 p.p.m., the sodium carbonate being somewhat higher, and the sodium chloride distinctly higher, though perhaps not excessive for a 'deep-seated' water.

"The water of the Taber well is more strongly saline than those discussed, with a total saline content of approximately 2,700 p.p.m. It has practically the same sodium carbonate content as the Government well No. 2, but contains much more sodium chloride.

"The water of the well 'south of Retlaw' is markedly the most saline of the series, with a saline content of approximately 6,000 p.p.m. In sodium carbonate, however, it is very similar to the waters of the three wells first considered, the additional salinity being due to a much larger sodium chloride content.

"The outstanding characteristics of these waters considered as a series are their practical freedom from calcium and magnesium compounds and their essential uniformity as regards sodium carbonate. It is the latter constituent which marks the element of danger in considering these supplies as water for irrigation purposes."

Dr. Shutt further adds that the waters from the three wells listed above "are undoubtedly too saline for use as irrigation waters."

NATURAL GAS.

Considerable development for natural gas has taken place in this map-area, and there are four well defined gas fields that are producing a large quantity of natural gas. These are the Medicine Hat field, with twenty-eight wells in 1925 with an estimated total production of 2,531,440,000 cubic feet; the Redcliff field with ten wells and an estimated open flow capacity of about 830,000,000 cubic feet; the Bow Island field which covers about twenty square miles near the town of Bow Island in Ranges 10 and 11. From this field gas is piped to the city of Calgary. The Burdett gas field is about six miles west of the Bow Island field. The indications suggest that this is a very large gas field, and possibly an oil field. The estimated gas available in the Burdett field is reported to be over 15,000,000 cubic feet per day. Considerable flows of gas have also been encountered in the Medicine Hat sheet at Many Island lake and at Alderson. Fuller discussion on the occurrence of gas in the Medicine Hat sheet cannot be given in this report.

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