CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report 1933, Part B

CONTENTS

OTTAWA
J. O. PATENAUDE
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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MICHEL COAL AREA, B.C., AND COLEMAN SOUTH COAL AREA, ALBERTA

By B. R. MacKay

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Illustrations

INTRODUCTION

During the field season of 1933 two important coal fields in the Crowsnest district of British Columbia and Alberta were examined and geologically mapped on a scale of 1 inch to 800 feet. These two areas are the Michel coal area, British Columbia, which is the most important coal field in western Canada and which has been under development for the past thirty-four years by the Crow's Nest Pass Coal Company, and the Coleman South coal area, one of the most important coal fields in southern Alberta, which has been under development for about thirty years by the International Coal and Coke Company. The position of these areas in relation to one another and to the four other coal areas previously mapped in detail is shown on Figure 1. In addition to this report hand-coloured geological maps and a transparent, coloured, celluloid structure-section model of each area, showing on natural scale the underground structure of the formations and coal seams and the extent of mine workings, were supplied to the respective coal companies at a nominal charge.

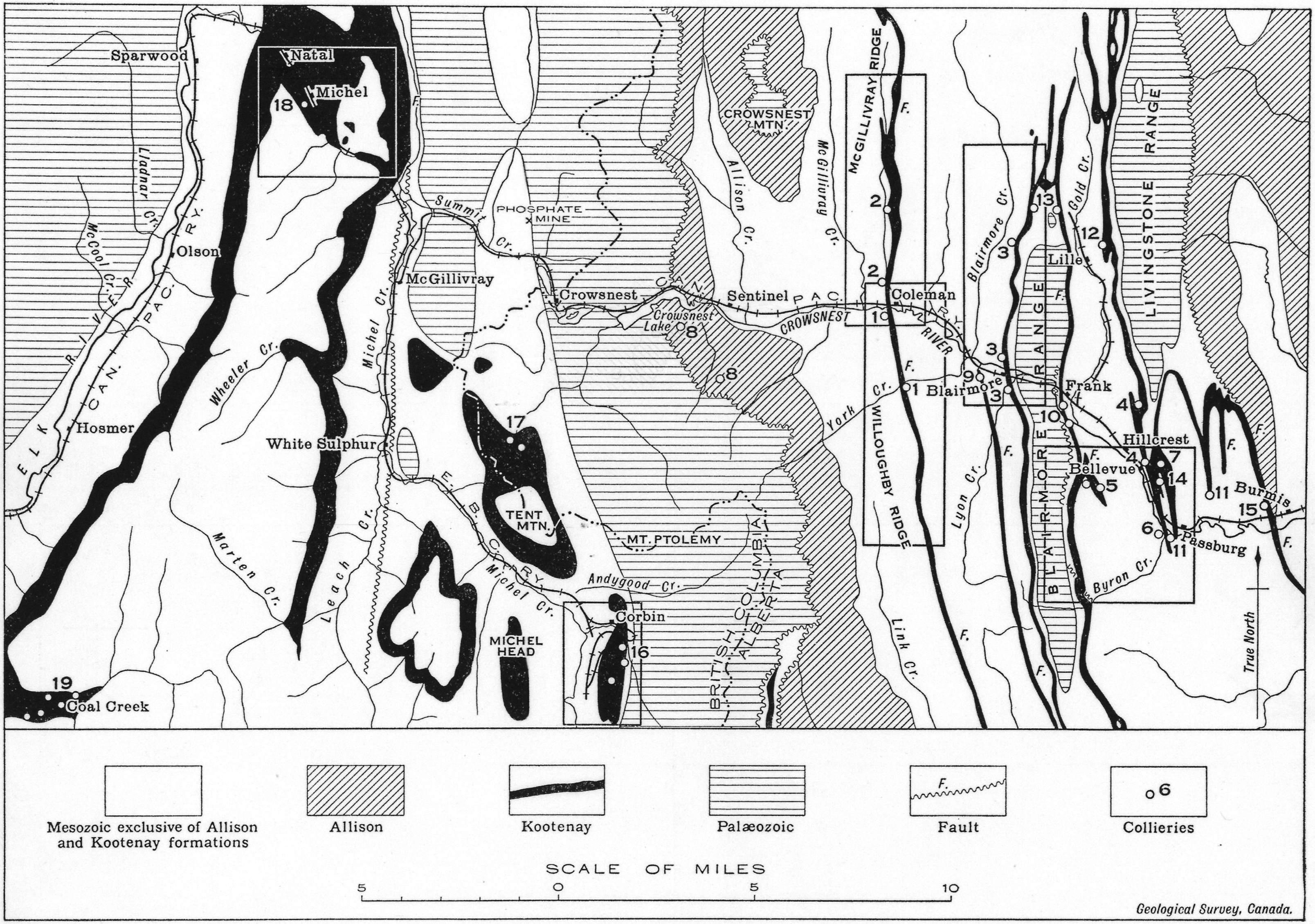


Figure 1. Index map of Crowsnest Pass area, British Columbia and Alberta. Areas of detailed mapping shown by rectangles; collieries are shown by numbers, for list *See* page 2.

LIST OF COLLIERIES (*See* Figure 1)

Operating Collieries, Kootenay Coal Deposits, Alberta

1. International Coal and Coke Company mines.
2. McGillivray Creek Coal and Coke Company mines.
3. West Canadian Collieries, Greenhill mines.
4. West Canadian Collieries, Bellevue mines.
5. Hillcrest Collieries mines.
6. Byron Creek Collieries mine (temporarily closed).
7. Mohawk Bituminous Mines.

Operating Collieries, Allison (Belly River) Coal Deposits, Alberta

8. Canadian-American Coal Company mines.

Abandoned Collieries, Kootenay Coal Deposits, Alberta

9. Cartwright and Thomason Sunburst mine.
10. Franco-Canadian Collieries mine.
11. Leitch Collieries mine.
12. West Canadian Collieries, Lille mine.
13. West Canadian Collieries, Grassy Mountain mines.
14. Maple Leaf Coal Company mine.
15. Burmis Mining Company mine.
17. Spokane and Alberta Coal and Coke Company mines.

Operating Collieries, Kootenay Coal Deposits, British Columbia

16. Corbin Collieries mines.
18. Crow's Nest Pass Coal Company, Michel colliery.
19. Crow's Nest Pass Coal Company, Coal Creek colliery.

MICHEL COAL AREA

GENERAL STATEMENT AND ACKNOWLEDGMENTS

Michel coal area is the most important coal field in western Canada, being characterized by numerous thick deposits of high quality bituminous coal, most of which are easily accessible. This area has attracted attention recently through its coal winning its way into the Winnipeg market and replacing large tonnages of high-grade coal from the United States. The Michel colliery, from which this coal was obtained, is operated by the Crow's Nest Pass Coal Company, Limited, and is situated on Michel Creek at a point 24 miles northeast of Fernie and 4 miles above the junction of Michel Creek and Elk River. The existence of coal in the area was mentioned by G. M. Dawson in Geological Survey Report 1885, page 69B. The coal was discovered through the denudation of Michel Creek which had cut its channel deeply into the Kootenay measures and exposed a number of seams on the opposite sides of the valley. With the opening up of railway communications in the Kootenay mining district by the Canadian Pacific Railway the Crow's Nest Pass Coal Company was formed to develop these deposits. This company began operations in 1899, and, with the exception of short periods during adjustment of agreements between the workmen and employers, coal mining has been carried on continuously since the start.

The colliery consists of two groups of mines, one group being located on the southwest side of Michel Creek and the other on the east side. The area underlain by mining operations is approximately 4 square miles and is bisected along a northwesterly direction by Michel Creek, along which runs the Crowsnest Branch of the Canadian Pacific Railway. The coal seams, where observed on both sides of the valley, dip 15 degrees to 20 degrees to the west, and this regularity of dip obtains over most of the mine workings, the deviations being due to the presence of a few minor folds and faults of small displacement. Notwithstanding the large amount of mining and prospecting work done in the area no satisfactory correlation had been made of the coal seams under development on the opposite sides of the valley. Various opinions were held, of which the most common was that the coal seams in the east side represented an older series, the uppermost of which, No. 9 seam, lay approximately 500 feet below No. 5 seam, the lowest coal seam exposed on the west side. Others maintained that No. 8 seam, the middle and most largely developed seam on the east side, was the same as No. 5 seam, on the west side, and still others held that this seam correlated with old No. 3 seam, which lay approximately 200 feet stratigraphically above No. 5 coal seam.

The correlation problem, although of considerable importance, became of secondary consideration when, in 1929, entirely unforeseen difficulties were encountered in the mine workings on the west side of Michel Creek. At a distance of approximately 3,000 feet from the mouth of the main crosscut tunnel a zone of faults and badly disturbed ground was encountered which not only disarranged mining operations but resulted in a large expenditure of capital in underground tunnelling and other prospecting. Finally, after tunnelling through a zone of over 200 feet of badly faulted

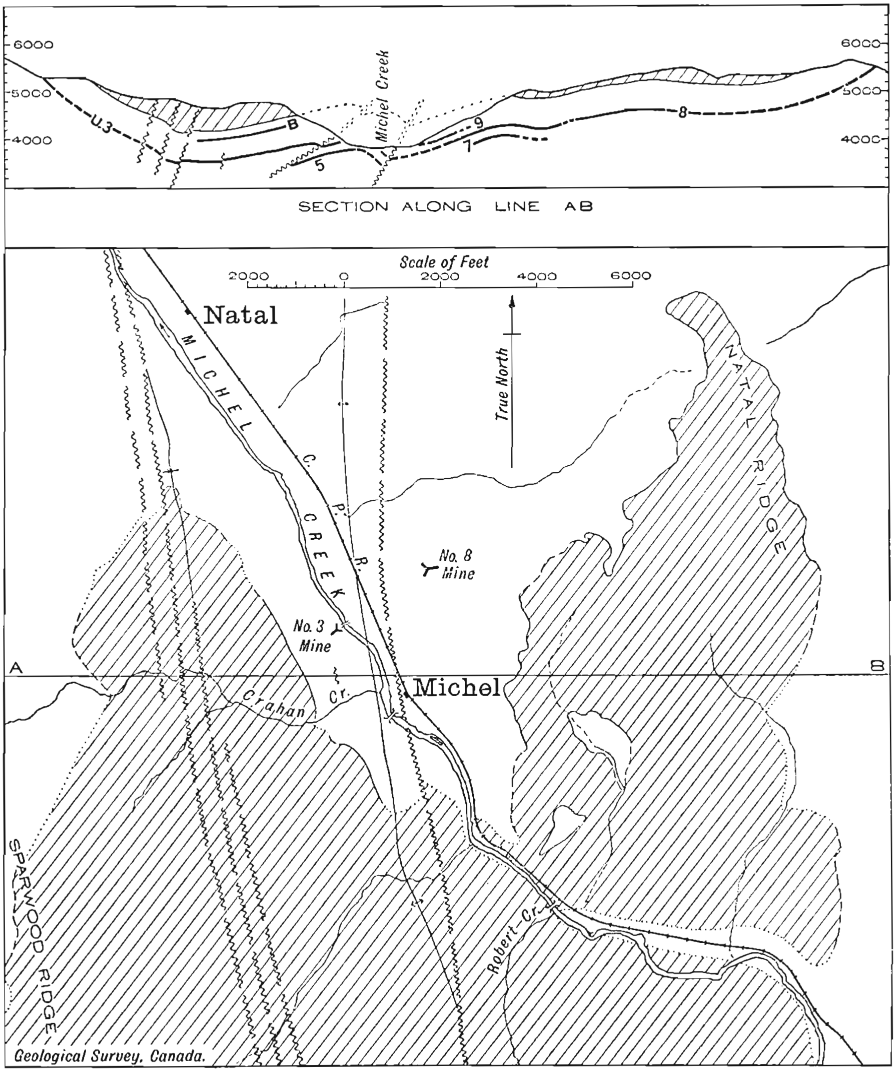
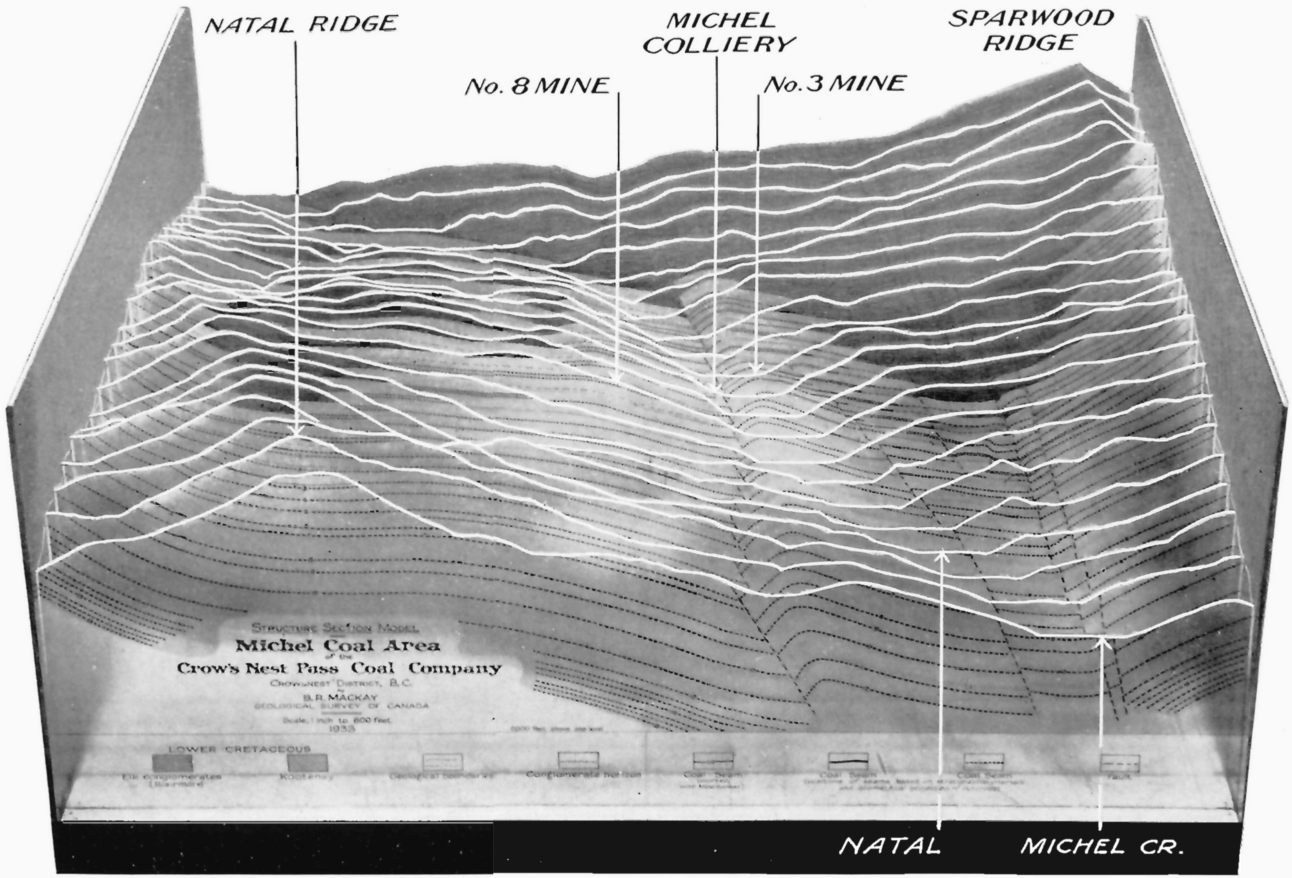


Figure 2. Crow's Nest Pass Coal Company, Limited, coal area, Michel, British Columbia (only certain of the coal seams being mined are represented in the cross-section). Blairmore shown by diagonal ruling; Kootenay shown by blank areas.



Geological structure section model of Michel coal area, Crowsnest Pass, British Columbia, looking south.

ground, coal seams were again encountered, but dipping in the opposite direction with dips as high as 45 degrees. These unexpected structural conditions not only resulted in a disarrangement of development plans and a heavy increase in mining costs, but caused so much concern on the part of the management with respect to the future development of this group of mines that early in 1931 an urgent request was made by the Crow's Nest Coal Company to the Department of Mines for a geological examination of the locality. Accordingly, in 1932 an area of 11·4 square miles, or $3\frac{1}{2}$ miles east and west and $3\frac{1}{4}$ miles north and south with Michel colliery as centre, was topographically mapped on a scale of 1 inch to 800 feet, and with a contour interval of 25 feet, by a party under J. A. Macdonald of the Topographical Division. This map served as a base for the geological mapping that was undertaken by a party under the writer's direction in 1933. The coal company aided materially in the carrying out of the investigation by furnishing office facilities, material, and mine data, and by supplying miners and a proper supervisor to carry out the necessary prospecting work. Thanks are especially due to Mr. H. P. Wilson, General Manager, Mr. R. L. Bonner, Colliery Manager, and Mr. John Heney, Mine Safety Inspector, of the Crow's Nest Coal Company, and to numerous other officers of the company's staff and to residents of the area for assistance rendered during the course of the work. The writer was assisted in the mapping by his colleague C. Evans, and by N. H. Fraser, J. M. Cummings, and R. L. Hewitt, who were attached to the party as student assistants, all of whom carried out the duties assigned them in a most efficient manner.

STRATIGRAPHY

There is exposed in Michel map-area (*See* Figure 2) a thick, conformable series of freshwater sediments of Lower Cretaceous age, as determined by the fossil plants that occur in the carbonaceous layers distributed throughout the series. The beds have a total thickness within the map-area of over 6,000 feet and were, in 1902, divided by James McEvoy on his map of the Crowsnest coal fields into two formations, the Crowsnest coal beds below, and the Elk conglomerates above. These formations conform in stratigraphic position, in flora content, and in their main lithological characters to the Kootenay and Blairmore formations, respectively, of Crowsnest district of Alberta (*See* Summary Report 1932, Part B, page 30), although in Michel area each has a much greater development. Since conglomerates form only a part of the upper formation and whereas the formations are undoubtedly the equivalents of the Blairmore and Kootenay formations, it appears advisable to use the latter formation names in describing them. The boundary between the Kootenay and Blairmore formations in this area is purely an arbitrary one, and is drawn at the base of the lowest massive conglomerate which persists over the map-area. All the commercial coal seams of the district lie below this conglomerate.

Kootenay Formation

The Kootenay formation (Crowsnest coal beds) consists of a thick series of interbedded, soft, sandy, grey and black, rusty-weathering shales, massive, coarse-grained, crossbedded, brown-weathering sandstones, with lenses and beds of fine conglomerate composed of pebbles of chert and quartzite of various hues firmly cemented in a sandy matrix. The formation contains in the neighbourhood of twenty-two workable coal seams, some of which have a thickness of 30 feet. The formation is of subaerial origin, as evidenced by the crossbedded and ripple-marked sandstones and by the innumerable dinosaur footprints observable over extensive areas on the roofs of some of the coal seams. Within some of the coal seams occur, individually or collectively in small nests of three or more, highly polished, smooth, waterworn chert and quartzite pebbles of various shapes ranging up to 5 inches in greatest diameter. A collection of fossil plants from the roof of Upper 3 coal seam were submitted to W. A. Bell, who reports as follows:

"The following five species were recognized:

Coniopteris sp.
Cladophlebis virginiensis Fontaine
Ptilophyllum arcticum (Heer)
Nilssonia schaumburgensis (Dunker)
Pityophyllum graminaefolium (Knowlton)

All species with the exception of the first are common components of the Kootenay flora. The species of Coniopteris occurs elsewhere sparingly in the Kootenay, but ranges upward into the Lower Blairmore flora where it is more common."

The most complete section of the formation occurs on the east side of Natal Ridge between the summit and Erickson Creek, which lies just beyond the northern border of the map-area. A section measured from the base of the massive conglomerate, taken as the boundary between the Blairmore and Kootenay formations, to within a few hundred feet of the fault contact with the Palæozoic gave a thickness of 3,610 feet with 206 feet of coal, and is as follows.

Section of Kootenay Formation

(As measured, in descending order, on east side of Natal Ridge, between summit of ridge and Erickson Creek)

Thickness in feet and inches	Description of beds
70	Coarse, crossbedded, medium grey, light greyish weathering sandstone, with conglomerate lenses
16	Conglomerate, composed of chert and quartzite pebbles $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, firmly cemented in a siliceous matrix; pebbles well rounded and predominantly light in colour; weathers light grey and red
7	Shale
4	Coal in dark, sandy shale
86	Hard, medium grey, sandy shale, weathering a light brownish grey
7 7	*Coal, Erickson No. 1 seam. Top*—30 inches coal, 19 inches coaly shale, 6 inches coal, 9 inches coaly shale, 15 inches coal, 4 inches grey shale, 8 inches coal, *base*
45	Hard, light bluish grey, rusty-weathering, sandy shale
24 2	*Coal, Erickson No. 2 seam. Top*—15 inches coal, 33 inches shale and coaly shale, 140 inches coal, 12 inches shale, 90 inches coal, *base*
43	Hard, medium grey, rusty-weathering, sandy shale

Thickness in feet and inches	Description of beds
1	Carbonaceous shale, containing 6-inch layer of coal
25	Hard, medium grey shale
30	Sandy shale, grading into fine, brownish grey weathering, hard, black and tan sandstone
64	Coarse grey sandstone, fine pebble conglomerate
22	Conglomerate, composed of chert and quartzite pebbles, ¼ to ½ inch in diameter, firmly cemented in siliceous matrix; bed contains lenses of coarse, dark grey sandstones
20	Hard, dark grey, light grey, and rusty-weathering, sandy shale
8 3	*Coal, Erickson No. 3 seam. Top*—8 inches coal, 12 inches shale, 69 inches coal, *base*
20	Dark grey shale
20	Covered interval
30	Medium-grained, brownish grey weathering, black and tan, crossbedded sandstone
40	Covered interval
15	Dark grey, rusty-weathering, sandy shale
25	Covered interval
15	Dark grey, shaly sandstone and sandy shale
10	Shale
16 7	*Coal, Erickson No. 4 seam. Top*—30 inches coal, 12 inches coaly shale, 157 inches coal, *base*
19	Dark grey, sandy shale
20	Covered interval
7	Medium-grained, brownish grey weathering, black and tan, crossbedded sandstone
30	Covered interval
10	Shale
5	Dark, carbonaceous shale containing 5-inch coal seam
35	Rusty-weathering, hard, grey, sandy shale
45	Covered interval
6	Medium-grained, rusty-weathering, black and tan sandstone
10	Covered interval
10	Dark, grey, rusty-weathering, sandy shale
12 8	*Coal, Erickson No. 5 seam. Top*—152 inches coal, *base*
10	Carbonaceous shale
35	Dark bluish grey, light grey, and rusty-weathering, sandy shale
60	Covered interval
10	Coarse, rusty-weathering, black and tan sandstone
10	Dark bluish grey, brownish-weathering, hard, sandy shale
110	Covered interval
12	Dark sandy, light grey weathering shale
7 6	*Coal, Erickson No. 6 seam. Top*—14 inches coal, 16 inches coaly shale, 60 inches coal, *base*
10	Dark sandy, light grey, and brown-weathering shale
80	Covered interval
20	Dark grey, hard, rusty-weathering, sandy shale
7 8	*Coal, Erickson No. 7 seam. Top*—52 inches coal, 24 inches shale, 16 inches coal, *base*
15	Hard, medium grey, brownish-weathering, sandy shale
110	Covered interval
18	Dark grey, brownish grey weathering, sandy shale
40	Covered interval
10	Hard, fine-grained, light grey weathering sandstone
65	Covered interval
35	Dark bluish grey, light grey weathering, sandy shale
0 3	Coal
25	Carbonaceous shale

Thickness in feet and inches	Description of beds
1	Coal and coaly shale
15	Bluish grey, rusty-weathering shale
70	Covered interval
20	Dark grey, rusty-weathering, sandy shale
15 5	*Coal, Erickson No. 8 seam. Top*—40 inches coal, 12 inches shale, 72 inches coal, 18 inches shale, 43 inches coal, *base*
80	Medium grey, rusty-weathering, sandy shale
80	Covered interval
35	Carbonaceous shale
3	*Coal, Erickson No. 9 seam. Top*—30 inches coal, 3 inches shale, 3 inches coal, *base*
10	Dark grey, brownish weathering, shaly sandstone
10	Fine, bluish grey, rusty-weathering sandstone
15	Covered interval
15	Carbonaceous shale, containing thin layers of coal and coaly shale
20	Covered interval
10	Fine, brownish grey, brown-weathering, shaly sandstone
40	Covered interval
20	Carbonaceous shale, containing 2-inch coal seam in centre
55	Covered interval
25	Dark shale
105	Covered interval
10	Dark grey, rusty-weathering, sandy shale
21 5	*Coal, Erickson No. 10 seam. Top*—21 feet 5 inches coal, *base*
20	Dark grey, rusty-weathering, sandy shale
85	Massive, coarse, dark grey, rusty and light grey weathering sandstone, with lenses of fine pebble conglomerate in places
1 8	Coal, with top unexposed, and floor of dark grey, shaly sandstone
50	Coarse, dark grey sandstone
15	Coarse, grey sandstone, with conglomerate lenses
75	Coarse, black and tan to light grey, reddish-weathering sandstone, with lenses of fine, pebble conglomerate
1 3	Coal
35	Medium-grained, black and tan weathering sandstone
25	Dark grey, sandy shale
0 6	Coal
35	Dark shale
0 3	Coal
20	Dark shale
20	Covered interval
24	Dark, brownish grey weathering, sandy shale
10 4	*Coal, Erickson No. 11 seam. Top*—20 inches coal, 10 inches shale, 8 inches coal, 6 inches shale, 34 inches coal, 6 inches coaly shale, 40 inches coal, *base*
15	Dark, rusty-weathering, sandy shale
25	Covered interval
10	Medium, brownish grey, rusty-weathering, shaly sandstone
65	Covered interval
15	Dark shale
2 5	Coal, with 4-inch band of shale in centre
30	Dark shale
60	Sandy shale
1 2	Coal
30	Dark brownish, shaly sandstone
12	Dark shale
6	*Coal, Erickson No. 12 seam. Top*—6 feet coal, *base*
10	Carbonaceous shale
40	Covered interval

Thickness in feet and inches	Description of beds
15	Coarse-grained, light grey, reddish-weathering sandstone, with a few lenses of fine pebble conglomerate
80	Covered interval
10	Dark, brownish-weathering, shaly sandstone
6	*Coal, Erickson No. 13 seam. Top*—6 feet coal, *base*
5	Shale
65	Covered interval
14 2	*Coal, Erickson No. 14 seam. Top*—12 inches coal, 24 inches carbonaceous shale, 108 inches coal, 6 inches shale, 20 inches coal, *base*
10	Dark, brownish grey, brown-weathering, shaly sandstone
0 6	Coal
2 6	Shale
0 4	Coal
50	Covered interval
10	Shale
9 4	*Coal, Erickson No. 15 seam. Top*—38 inches coal, 30 inches dark shale, 8 inches coal, 6 inches shale, 30 inches coal, *base*
110	Covered interval
5	Shale
16 2	*Coal, Erickson No. 16 seam. Top*—60 inches coal, 24 inches shale, 110 inches coal, *base*
5	Shale
50	Covered interval
5	Shale
7 3	*Coal, Erickson No. 17 seam. Top*—24 inches coal, 18 inches shale, 45 inches coal, *base*
10	Shale
80	Covered interval
10	*Coal, Erickson No. 18 seam.* Shale, with coal bloom, not sectioned
50	Covered interval, base of Kootenay formation unexposed
3,576 4	Total thickness of Kootenay formation

The Kootenay formation is exposed over a little more than half of the map-area, being concentrated largely in the northern part of Michel Valley, the eastern slope of Natal Ridge, and the northern end and western slope of Sparwood Ridge. The irregular boundary of the area occupied by the formation is determined by the combination of the 2,800 feet of relief of the area, the course of Michel Creek Valley, and the southerly plunge of the folds in the sediments. Where the Kootenay formation is exposed valleys and gullies were easily cut into it, as illustrated in the large gullies opposite Natal. Erosion of the Blairmore formation in the valleys of two small streams located 4,300 feet southeast and south-southeast of Michel Station has exposed two, small, elliptical areas or "windows" of Kootenay rocks.

Blairmore Formation

The younger formation in Michel map-area is made up of alternating, hard, grey, greenish, and yellowish sandstones, massive conglomerates, soft, light brown weathering shales, thin coal seams, and, in the upper part, two or more thin beds of freshwater limestone. Although many of the sandstones and conglomerates grade laterally into one another, there are six massive beds of conglomerate ranging from 20 feet to 80 feet in thickness which are sufficiently persistent to be traced. The formation is estimated to have a total thickness in the basin of over 6,500 feet, only the lowermost 2,400 feet of which occurs within the borders of Michel map-area. This maximum thickness occurs at the southern border of the area in the centre of the southerly plunging syncline a mile east of the southwest corner of the sheet. Of the six conglomerates the lowest occurs at the base of the formation and the others occur at approximately 360 feet, 1,280 feet, 1,530 feet, 1,660 feet, and 1,800 feet above the base. Each of these conglomerates is made up of pebbles of quartzite and chert of various hues and of dimensions ranging up to 5 inches in diameter. They are so firmly cemented in the sandy matrix that when broken the cleavages cut across pebble and matrix alike.

Formerly the Blairmore formation completely covered the area and it is due to the resistance to weathering of its hard, massive conglomerate beds that the coal deposits have been preserved over so much of the area and have been protected from being crushed in the southerly plunging Sparwood syncline. Michel Creek has cut completely through the Blairmore formation except for a distance of approximately 2,000 feet, so that the formation now underlies two main areas, one lying east and the other west of the creek.

STRUCTURE

Michel map-area covers the northern and narrow end of the pear-shaped Crowsnest coal basin, which in the vicinity of Michel is about 5 miles wide and plunges southward at the rate of about 100 feet in 800 feet. The northern trough of the basin is designated the Sparwood syncline. Its southerly trending axis crosses Michel Creek at Natal townsite at the northern border of the map-area. Lying close to and paralleling the axis of the syncline are several closely spaced, normal faults of comparatively small displacement. The western limb of the syncline has an average uniform dip of 25 degrees east, the eastern limb is more gentle and is modified by an anticlinal fold whose eastern limb is faulted and the west fault block has been thrust several hundred feet upward and eastward. The axis of this anticlinal fold is observable in the small creek channel on the hillslope east of Natal townsite, at Michel road bridge, and in the working of 3-East mine a half mile south of the bridge. Traced southward the fold gradually dies out. The thrust fault is less clearly defined, owing to the heavy blanket of glacial drift, but its position is indicated by the abrupt change in dips of the beds observed at intervals along its course. Farther up the eastern limb of the main synclinal fold occurs a shallow, southerly plunging, anticlinal fold, which in turn is succeeded by a gentle, southerly plunging syncline, the axis of which passes through the summit of Natal Ridge. A few faults of small displacement occur on this limb.

Over much of the area no structural data could be obtained owing to the bedrock being concealed by a heavy mantle of boulder clay or talus and by forest growth. The strongly crossbedded character and the massiveness of the coarse sandstones and conglomerates made difficult the determination of their correct inclination. The rapid variation in beds made the correlation of different sections almost impossible unless these are checked by the stratigraphic interval from some persistent horizon such as a shale bed or a coal seam. Wherever possible the horizons were instrumentally traced and the intervals between them and some major horizon accurately determined, and this interval was used in checking the dip readings and in determining the correction that should be applied to them to ascertain the true inclination of the crossbedded sediments. In some cases a reduction of as much as 10 degrees had to be applied to the observed dip of the foreset beds.

MINING DEVELOPMENT AND COAL DEPOSITS

Mining operations began at Michel in 1899, and are carried on in two groups of mines. Those on the east side of Michel Creek comprise No. 8 mine, No. 9 mine, and No. 7 mine, each of which is located on a seam designated by the same number, No. 9 seam being the uppermost seam worked and No. 7 seam being the lowest. These seams outcrop at intervals on the northeastern part of the map-area high up on the hillslope to the east of Natal townsite. No. 8 seam was the first to be opened up, and on it have been developed two mines which have a combined area of almost a square mile. No. 9 seam lies approximately 90 feet stratigraphically above No. 8 seam, from which it was reached by a crosscut tunnel. Very little development work has been done on this seam. No. 7 seam where prospected lies approximately 170 feet stratigraphically below No. 8 seam. It was reached by a tunnel 450 feet in length driven from No. 8 seam. It was later opened up by levels driven northward and southward from the seam outcrop on a creek at a point 2,000 feet north of the tipple.

On the west side of Michel Creek mines have been opened up on eight coal seams, all of which, with the exception of the uppermost seam, designated "B" seam, are intersected by a main cross-measure tunnel. In ascending order these are: No. 5 seam, 8 feet thick, intersected at 240 feet from the entry; No. 4 seam, 12 feet thick, intersected at 600 feet; Lower 3 seam, 6½ feet thick, cut at 960 feet; Upper 3 seam, 12 feet thick, intersected at 1,540 feet; No. 2 seam, 7 feet thick, intersected at 1,740 feet; No. 1 seam, 11½ feet thick, cut at 1,800 feet; A seam, 18 feet thick, cut at 2,700 feet; and B seam, 6 feet thick, and lying 120 feet stratigraphically above A seam, reached by an incline driven from A seam where it is cut by the tunnel. An undeveloped seam, 2 feet in thickness, lies 36 feet stratigraphically above "B" seam and approximately 150 feet below the top of the Kootenay formation. Brief descriptions of the mine workings on each of the above-mentioned seams follow.

No. 8 Mine

No. 8 mine is the largest mine in the colliery, underlying an area of almost 1 square mile. It is located on the east side of Michel Creek. The coal seam ranges from 4 to 30 feet in thickness, averages 12 feet thick, and dips 15 to 30 degrees west. The coal is an excellent steam and coking coal. Mining began in 1899 by an adit driven into the seam at tipple elevation 48 feet above Michel Creek. The main or No. 1 level was driven southeasterly in the seam and the seam was blocked out by levels, inclines, and rooms to a height of 470 feet above the main level, covering an area about 1,500 feet wide and 6,800 feet long. On May 15, 1911, a fire, thought to have been caused by spontaneous combustion, was discovered in the abandoned workings of No. 3 east level. This spread so rapidly through the workings that the mine had to be sealed off, and these workings have never been reopened. In 1913 the upper and northern part of No. 8 seam, known as New No. 8 mine, was opened by a prospect tunnel 400 feet long, driven at a point 535 feet above the tipple and 2,300 feet north of it. The seam here has an average dip of 15 degrees west. About 12 feet of the seam is mined. This mine has been in operation almost continuously from 1913 to 1932 and for many years it ranked as one of the best producers in the colliery. An area about 5,000 feet along the strike and 3,500 feet up the dip has been developed to date. The loaded cars from the mine were weighed at the top of the incline where the coal was dumped into bunkers, then loaded into skips and lowered by gravity to where it was again dumped into bunkers situated at the bottom of the incline. Here it was loaded into mine cars which were conveyed to the tipple by endless rope haulage. No. 8 mine is now permanently abandoned, but the coal seam can be readily reopened at another point should conditions warrant it.

No. 9 Mine

Only a small amount of development work has been done in No. 9 mine. It is located immediately north of Michel Creek, on the seam designated by the same number. This seam varies from 8 to 10 feet in thickness. The mine was operated from 1900 to 1904, being connected by a cross-measure tunnel driven from the main east level in No. 8 mine. It has been idle since 1904.

No. 7 Mine

No. 7 mine is a small mine opened up in No. 7 seam. This seam is of hard, strong coal, with a hard roof. It has a thickness of 14 feet and consists of a 7-foot bench of bottom coal, a 3-foot shale, and a 4-foot top coal. It was correlated with No. 5 seam on the west side of Michel Creek mine and was opened by a cross-measure tunnel driven from a point on main east level of No. 8 mine. From 1901 to 1911 levels were carried east and west from the cross-measure tunnel, a distance of 1,600 feet and 2,000 feet, respectively, and a small amount of development work on the dip was done. Work ceased on March 31, 1911. In 1913 prospect levels were carried in the coal from its outcrop in a creek valley. These levels went 800 feet north of the tipple, a distance of 700 feet west, and were stopped in 1919. In 1925 a prospect, located 1,000 feet west of the entrance of No. 8 mine and known as No. 8 Prospect drift, was opened for the purpose of proving No. 7 seam. The seam was reached at a distance of approximately 500 feet from the entrance, but did not prove sufficiently attractive to warrant development.

No. 5 Mine

The operations on the west side of Michel Creek began shortly after the beginning of development work in No. 8 seam with the driving of the main cross-measure tunnel from track level southwesterly into the hillslope to intersect the several westerly dipping seams which had been discovered outcropping on this valley slope.

The tunnel cut No. 5 seam in 1902 and levels were run to the north and south. A slope was sunk in the seam from a point 150 feet south of the tunnel intersection and from it levels were run to the north and south. Work was in progress in this mine until 1911, with the exception of 1905 when a strike was on and the mine became flooded. In 1911 when work was terminated through difficulty in coping with water, the slope had been driven down a distance of over 1200 feet. The workings extended southward from the slope a distance of 2,000 feet and for an average depth of 1,000 feet. The distance the workings extended northward ranged from 800 feet at the lowest level to 2,000 feet at No. 2 west level, work in this direction being stopped through the encountering of faulted ground.

The coal seam near the outcrop west of this fault was worked by means of a short tunnel driven westward of a point on the south bank of Michel 1,300 feet south of the main tunnel. These workings were started in 1903 and were designated the No. 6 mine. Operations were carried on in this mine until the last few months of 1906 when work was discontinued. The workings consisted mainly of a driving of a level and counter level in the coal westerly for a distance of 1,500 feet from the mine opening to where it was stopped by a fault of considerable magnitude.

No. 4 Mine

No. 4 seam, ranging from 8 to 30 feet in thickness and averaging 12 feet thick, was the second coal seam cut in the cross-measure tunnel. The coal was clean and of good quality. The roof in some places is soft, whereas in other places it is so hard that very little timbering is required. Development work began in this seam in 1903 with the driving of a level eastward and westward. From a point in this level 30 feet east of the tunnel a slope was sunk from which levels were driven and from these other slopes were sunk, the lowest level lying about 250 feet below the elevation of the top of the slope. The seam was also developed up the dip to its outcrop, which lay from 100 to 150 feet above this level. These workings were also driven southeasterly and connected up with a slope that was driven westward down the coal seam from the end of a 160-foot tunnel located at a point 1,200 feet east of the mouth of the main cross-measure tunnel.

No. 3 Mine

This mine operates on Upper No. 3 seam, Lower No. 3 seam, No. 2 seam, and No. 1 seam.

Lower No. 3 Seam. Lower No. 3 seam was the third seam reached in the cross-measure tunnel and was entered at a distance of 960 feet from the tunnel mouth. It has a thickness of 6½ feet. Operations began in this mine in 1902 and with the exception of the years 1903, 1904, 1905, and part of 1906, the mine has been in almost continuous operation, and during 1913 to 1916, inclusive, No. 3 mine and No. 3 East mine were the only two producing mines on the west side of Michel Creek. Mining began with the driving of a main level along the seam in both directions from the tunnel. From a point 170 feet east of the tunnel No. 2 slope was sunk down the seam, which dipped westward at an angle of 15 degrees. This slope and the workings west of it ultimately reached a distance of 1,600 feet. From a point on the main level, 1,000 feet north of No. 2 slope, another slope, No. 3 slope, was driven down the seam. By 1913 this slope had reached a distance of over 800 feet. Here, at a point approximately 2,000 feet west of Michel Creek, and near the centre of the Sparwood syncline, the coal seam was faulted. This necessitated the driving of a tunnel westward from the bottom of the slope. In 1914, after driving this tunnel 200 feet, a coal seam was encountered which later proved to be Upper No. 3. The slope was continued in Upper No. 3 for 300 feet and a second fault was encountered. A horizontal tunnel was driven for a distance of 180 feet, and encountered a seam that later proved to be No. 2 seam. Work was continued in the seam until 1916, but the friable nature of the coal and the considerable quantities of dust produced in mining forbade any blasting being carried on in any part of the mine that was dry. From 1917 to 1927 practically no development work was carried on in this seam beyond keeping the airways and roadways open. In 1927 the seam was again under development and this has continued to the present. In 1931 and 1932 the water was allowed to accumulate in the dip workings, and that part of the mine has been temporarily abandoned.

Upper No. 3 Seam. In 1918 the cross-measure tunnel was continued from Lower No. 3 seam 480 feet to intersect Upper No. 3 seam lying approximately 150 feet stratigraphically above it. This seam is 12 feet thick and consists of hard coal. Levels were driven in both directions and a slope driven on the full dip of the seam 70 feet to the south of the main tunnel. This slope was driven a distance of 1,300 feet to where a fault was encountered near the bottom of the Sparwood syncline or 3,800 feet from Michel Creek. This necessitated the driving of a rock tunnel 500 feet long. Pockets of coal were encountered in this tunnel, but they did not conform to the regular seams. At 500 feet a seam was encountered dipping 45 degrees east. Levels were driven to the south in this seam for a distance of 500 feet, but owing to the faulted conditions encountered work was discontinued in October, 1930. The levels to the south in this seam, together with the workings south of the main slope, extend about 500 feet from the main slope to a barrier pillar left between these workings and those from the same seam worked from No. 3 East mine. The west levels encountered a fault at 2,600 feet: after penetrating this, the strike line changed 60 degrees to the left. The levels were extended 800 feet farther when another and larger fault was encountered. Between the two faults, inclines were driven to the outcrop and slopes to the main fault. A horizontal tunnel 350 feet long, driven from the main level, encountered the seam on the west side of the Sparwood syncline, the seam dipping 20 degrees to 50 degrees to the east. Levels to the south extended 1,800 feet to where faulted ground caused their temporary abandonment. Inclines were driven across the pitch and paralleling the fault a distance of 2,300 feet and gained in elevation 700 feet above the main level. These inclines will outcrop in Michel Valley about opposite the north end of Natal townsite. Development work in the area is being carried on at the present time, the method of operation being room and pillars.

Prior to the development of the seam through the main cross-measure tunnel in 1902, operations had been begun in the eastern part of this seam, known as No. 3 East mine. Work in this mine was discontinued shortly after, but the mine was reopened in 1910 by a tunnel driven in the coal from a point on the west side of Michel Creek 1,900 feet south of the tipple. From this tunnel a slope was carried down the full dip of the seam, and, after passing through a normal fault of small displacement at a point about 1,200 feet from the tunnel mouth, it has now reached a distance of 2,500 feet from the tunnel entry. From this slope the main slope on the west, and No. 6 slope on the east, side of the developed area have been carried along this easterly plunging anticline, the former for a distance of 3,000 feet and the latter for a distance of 2,000 feet. In this mine the seam averages 10 feet in thickness. The mine was badly wrecked by an explosion on August 8, 1916, about 75 per cent of the roadways being caved. Mining operations were carried on in this seam until 1922 when work was discontinued. The only attention it has received since has been the maintenance work and the sealing off of areas where heating was in evidence.

No. 2 Seam. No. 2 seam lies approximately 60 feet above Upper No. 3 seam. It varies in thickness from 5 to 6 feet and has a shale roof and a sandstone floor. Mining operations began in No. 2 seam in 1923 by the driving of a crosscut tunnel approximately 200 feet in length from the main east level of Upper No. 3 seam. It was worked until 1926 when work on it was discontinued. In 1927 it was reopened by the continuation of the main tunnel from Upper No. 3 seam. Only a relatively small amount of development work has been done on it.

No. 1 Mine

No. 1 Seam. No. 1 seam was entered in 1925 by a crosscut tunnel, 100 feet in length, from No. 2 seam main level. Main levels and connexions for ventilation purposes were laid off and development work was carried on by inclines up the dip of the seam until 1926 when mining operations were discontinued. The seam was reopened in 1927 by the continuation of the main crosscut tunnel driven from Upper No. 3 seam, and the workings of Nos. 1, 2, "A," and "B" seams were afterwards included under the name No. 1 mine. No. 1 seam was actively developed in 1929 and 1930.

A Seam. "A" seam, 18-23 feet in thickness, was intersected by the cross-measure tunnel in 1928 at a distance of 2,850 feet from Michel Creek. Levels were driven to the south for a distance of 600 feet. In 1929 work was suspended due to market conditions. The seam consists of two benches separated by a zone 3 feet thick of shale, bone, and dirty coal. The lower bench is 7 to 10 feet thick and the upper bench is 8 to 10 feet thick. The soft nature of the coal and the great thickness of the seam necessitate the coal being mined in benches.

B Seam. "B" seam is the uppermost coal seam being mined and averages from 5 to 5½ feet in thickness. It has a strong shale roof in which "pots" or "bells," having depths ranging up to 4 feet and maximum diameters of 7 feet, are of frequent occurrence. It was intersected in 1927 by a 350-foot tunnel driven southerly from the main cross-measure tunnel at a distance of 3,000 feet from Michel Creek. The workings on this seam were systematically planned from the commencement of operations with the view of introducing the retreating long-wall method of mining. From the tunnel, levels have been driven 1,000 feet to the east and 800 feet to the west, and entries are being driven in a northwesterly direction parallel to the Sparwood syncline. Inclines in the main east level and the above entries are being driven toward the outcrop; one incline was put through for ventilating purposes. The coal is extracted on the retreating long-wall system, the mine being partly mechanized.

Total Production

The yearly production of Michel Colliery from the end of 1933 to the commencement of operations in 1899 is as given below, the total production from this colliery to date being slightly below 9,500,000 tons:

Year	Short tons	Year	Short tons
1933	231,382		
(after deducting 4,251 tons of refuse		1915	311,500
from cleaning plant)		1914	225,238
1932	243,405	1913	242,171
1931	277,217	1912	284,324
1930	297,429	1911	128,112
1929	383,200	1910	512,490
1928	402,693	1909	437,318
1927	399,500	1908	461,647
1926	407,450	1907	396,176
1925	360,120	1906	306,315
1924	165,541	1905	309,506
1923	289,441	1904	263,487
1922	243,029	1903	263,590
1921	311,700	1902	127,515
1920	296,343	1901	52,763
1919	193,611	1900	11,162
1918	231,183	1899	438
1917	142,382		
1916	273,412	Total production to Dec. 31, 1933	9,482,790

CORRELATION OF COAL SEAMS

The extensive mining development work done on the two groups of mines on the opposite sides of Michel Creek, the bore-hole records and data furnished by numerous surface prospects, together with data obtained from the recent geological investigations, have amply demonstrated that although the individual coal seams are remarkably persistent over extensive areas, their thicknesses and character change laterally and the intervals between the coal seams vary greatly within short distances. The variations in the distance separating one seam from another are in part due to minor faulting, pinching, and crushing of the measures, and, in part, to the lens-like form of the intervening beds of sandstone and shale, which is clearly observable in the field.

The presence of at least eleven developed seams of humic coal distributed through a stratigraphic thickness of 1,600 feet of measures offered an exceptional opportunity to test the application of Hilt's Law, which states that the deeper the coal seam the smaller the percentage of volatile matter contained in the coal, or, in other words, the greater should be the fuel ratio (F.B.), namely $\frac{\text{Fixed carbon}}{\text{Volatile matter}} \left(\frac{\text{F.C.}}{\text{V.M.}}\right)$. Accordingly, fresh samples from each of these eleven developed seams were collected. These have been analysed by the Fuel Testing Laboratories of the Department of Mines and the results are shown in Table I. The fuel ratios are given in the following table, in which the coal seams of each group are listed in descending order.

—	Seam	Fuel ratio
Group 1: west side of Michel Creek	No. B seam	2·75
	No. A "	2·70
	No. 1 "	2·80
	No. 2 "	2·80
	No. U3 "	2·95
	No. L3 "	3·05
	No. 4 "	3·25
	No. 5 "	3·05
Group 2: east side of Michel Creek	No. 9 "	2·80
	No. 8 "	2·85
	No. 7 "	2·90

The values of the fuel ratio suggest that Hilt's Law is applicable to Group 2 and, with two exceptions, to Group 1, and that the coal seam 9 of Group 2 is the equivalent of seams 1 and 2 combined, 8 of U3, and 7 of L3, respectively. If such is the case, the areas underlain by the two groups must be separated by a fault along which the seams of Group 1 have been thrust up several hundred feet relative to those of Group 2. The existence of such a fault was established by field work.

The best guide to the relative horizons of the coal seams on the opposite sides of Michel Creek is the persistent, massive conglomerate chosen as the base of the (Elk conglomerates) Blairmore formation. This conglomerate has been traced instrumentally wherever exposed throughout the map-area. Over much of the area, on both sides of Michel Creek, it overlies large areas that have been mined and it was possible at many places to determine the interval between the base of the conglomerate and particular mine workings on either side of the creek. Numerous determinations were made of the interval between the conglomerate and the workings in No. 8 mine (No. 8 seam) on the east side, and between the conglomerate and the workings in Upper 3 mine (Upper 3 seam) on the west side. The interval between the basal conglomerate and the two seams wherever it could be determined was practically the same, i.e. 580 feet to 600 feet, so that with the stratigraphic horizons and fuel ratios of these two seams checking so well, there appears to be little doubt that they represent the same coal seam.

This correlation of the seams on the two sides of Michel Creek, if correct, indicates that east of Michel Creek there probably are present seams lower than those that have been mined. Such a conclusion is also supported by the fact that nearby, at Sparwood, there are at least twenty-two commercial seams. On the east side of Michel Creek, three bore-holes were drilled some years ago, but the deepest reached only a short distance

Table I. Proximate Analyses of Coal Seams being Mined at Michel Colliery, Michel, Crowsnest District, B.C.

(Samples taken by B. R. MacKay, June and July, 1932, and analysed by Fuel Testing Laboratories, Mines Branch)

Lab. No.	Description and location of sample	Form of analyses	Moisture	Ash	Vol. matter	Fixed carbon	S	Heating calories	Value B.T.U's.	Fuel ratio	Coking prop.	Softening temperature of ash
10,872	No. 9 seam, lump sample taken in No. 9 off No. 8 main haulage	A[1] B[2]	3·0	5·2 5·3	24·1 24·9	67·7 69·8	0·4 0·4	7,970 8,225	14,350 14,800	2·80	Good, much swollen	Initial above 2,700° F.
10,874	No. 8 seam, 50 feet in No. 2 room, B incline	A B	2·6	5·1 5·2	23·9 24·5	68·4 70·3	0·6 0·7	7·905 8,120	14,230 14,610	2·85	Good, much swollen	Initial above 2,700° F.
10,873	No. 7 seam, about 800 feet in New No. 7 tunnel	A B	2·5	13·7 14·0	21·6 22·2	62·2 63·8	0·6 0·6	7,170 7,355	12,910 13,240	2·90	Good	Initial above 2,700° F.
10,870	No. B seam, face of main west level	A	1·4	6·6 6·7	24·7 25·0	67·3 68·3	0·7 0·7	7,980 8,090	14,360 14,570	2·75	Good, much swollen	Initial above 2,700° F.
10,869	No. A seam, crosscut between main east level and counter level	A B	1·7	13·4 13·6	23·1 23·5	61·8 62·9	0·4 0·4	7,250 7,370	13,050 13,270	2·70	Good, much swollen	Initial above 2,700° F.
10,871	No. 1 seam, across face of counter	A B	1·6	5·8 5·9	24·4 24·8	68·2 69·3	0·4 0·4	8,075 8,210	14,540 14,780	2·80	Good, much swollen	Initial above 2,700° F.
10,867	No. 2 seam, off main tunnel......	A B	1·7	7·1 7·2	24·1 24·5	67·1 68·3	0·5 0·5	7,930 8,070	14,270 14,520	2·80	Good, swollen	Initial above 2,700° F.
10,865	Upper 3 seam, east level main tunnel	A B	2·0	6·7 6·8	23·0 23·5	68·3 69·7	0·6 0·7	7,900 8,065	14,220 14,520	2·95	Good, much swollen	Initial above 2,700° F.
10,866	Lower 3 seam, 50 yards main west level	A B	1·7	14·3 14·5	20·7 21·0	63·3 64·5	0·6 0·7	7,235 7,360	13,020 13,250	3·05	Good, much swollen	Initial above 2,700° F.
10,913	No. 4 seam, main tunnel..........	A B	2·4	7·1 7·3	21·4 21·9	69·1 70·8	0·6 0·6	7,780 7,975	14,000 14,350	3·25	Good	Initial above 2,700° F.
10,868	No. 5 seam, east level off counter slope	A B	2·1	10·8 11·1	21·6 22·1	65·5 66·9	0·5 0·5	7,435 7,600	13,380 13,680	3·05	Good, much swollen	Initial above 2,700° F.

[1]A=As received basis.
[2]B=Dried basis 108 degrees.

below the lowest seam being mined on the west side. The desirability of determining the presence or absence of lower seams caused the writer to suggest the prospecting of the east slope of Natal Ridge from its summit to Erickson Creek, where, with trenching, an almost complete section of the Kootenay measures could be secured. A prospecting party of six miners and a competent foreman were placed at his disposal to do the necessary trenching, and in a period of three weeks a geological section of the Kootenay formation from the top to near its base was obtained, and the existence, horizons, and thicknesses of seventeen coal seams of 3 feet or more in thickness were established (*See* Details of section, pages 6 to 9).

The east slope of Natal Ridge is so covered with talus and boulder clay that the seams uncovered could not be traced along the slope for any great distance. However, coal bloom indicating the presence of seams was observed and instrumentally located at a number of these places which, when checked by the stratigraphic interval between them and the base of the conglomerate marking the top of the Kootenay formation, were found to indicate the horizons of a number of the seams. It will doubtless be found with further prospecting by trenching or drilling that some of the seams will be found to end or to become non-commercial, or that the interval between the seams changes, or that seams appear that are not indicated in the section on the east slope of Natal Ridge. For example, in this section no trace was found of coal at the horizons of seams B and 2 of the west side of Michel Creek, but the equivalents of these will likely be established with further exploration work.

In the mine workings on the west side of Michel Creek there exists a low-angle thrust fault, on the east side of which are segments of four seams, the lowest of which is designated as seam 5 (*See* Figure 2). The thicknesses and other characteristics of the seams suggest that No. 5 seam is the same as the Lower 3 to the west of this fault and that No. 4 (immediately overlying No. 5) seam is the same as Upper 3, and the two remaining seams of the group east of the thrust fault are, in ascending order, the faulted segments of seams 2 and 1 on the west side of the fault. Assuming the above correlation to be correct, as we have every reason to believe it is, the eleven seams on which mines are located represent segments of only six seams which, in descending order, are B, A, 1, 2, U3, and L3.

COLEMAN SOUTH COAL AREA

GENERAL STATEMENT AND ACKNOWLEDGMENTS

In 1933 a detailed investigation was made of the Coleman South coal area, which for the past thirty years has been held and developed by the International Coal and Coke Company, its total coal production approximating 7,000,000 tons.

The Coleman South map-area reaches from the northern boundary of Sec. 8, Tp. 8, Range 4, W. 5th Mer., southward to a little beyond the centre line of Secs. 8 and 9, Tp. 7, Range 4, W. 5th Mer., a distance of slightly over 6½ miles. This map-area is 2 miles in width and has as its centre line the boundary between sections 8 and 9. It covers the outcrops

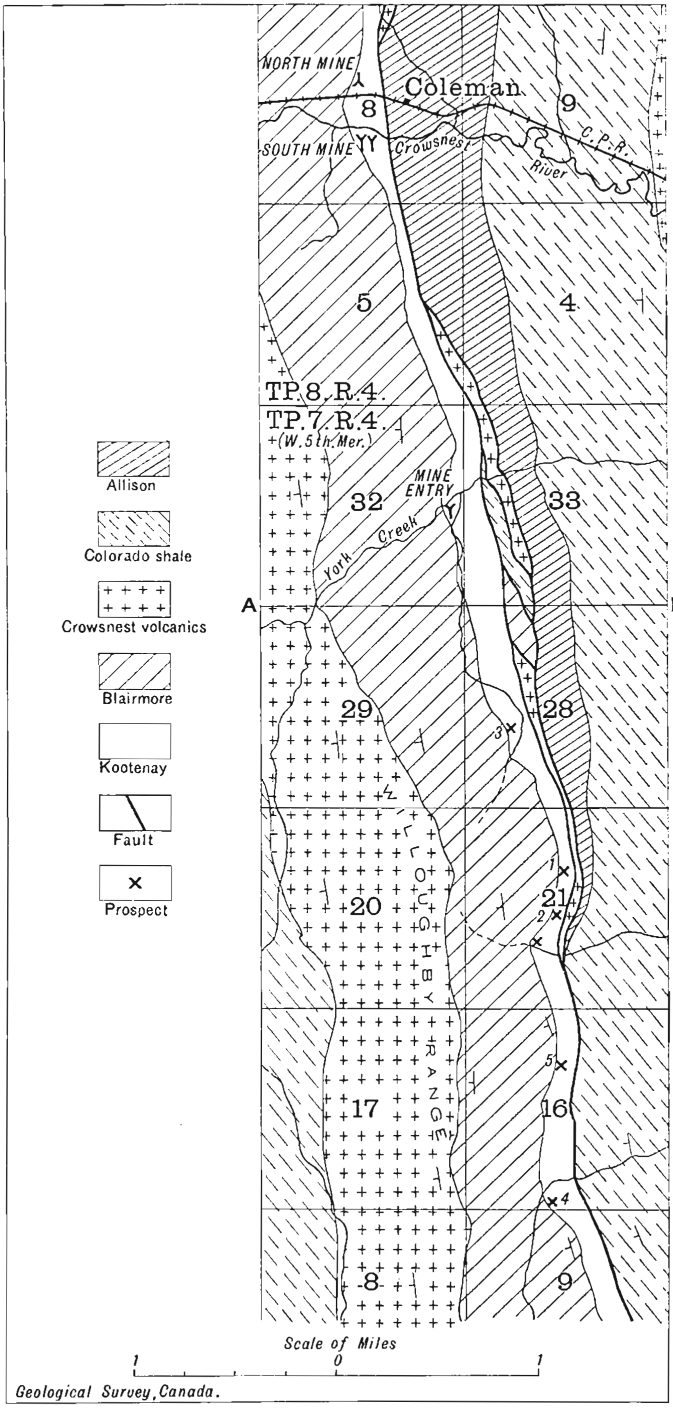


Figure 3. International Coal and Coke Company, Limited, coal area, Alberta.

of the several coal seams and, except the northern end, as far down their dip as it will be practicable to mine for many years to come. At the northern end of the map-area the International Coal and Coke Company property extends a half mile west of the border of the area mapped, and the mine workings will be carried probably considerably farther down the dip than they are at present. The coal measures and seams are remarkably uniform in strike and dip over the map-area. They strike a little east of south and dip from 30 to 40 degrees west (*See* Figure 4). At Coleman the coal measures contain a maximum of five seams designated, in descending order, as seams 1, 2, 3, 4, and 5, only two of which, i.e. seams 2 and 4, are of sufficient purity to be commercial.

The problem the International Coal and Coke Company will eventually have to contend with is due to the convergence southward, and increasing dirtiness, of the two seams under development. Over most of the area bedrock is concealed beneath a heavy mantle of boulder clay, and to determine the character of the two seams south of the mine workings and the varying interval between them necessitated considerable trenching. For this work the company assigned a small party of miners to work in close co-operation with the Geological Survey party. The seams were open at five localities in Secs. 28, 21, and 16, Tp. 7, Range 4, W. 5th Mer., and were sectioned. The trenches were not sunk deep enough to obtain fresh coal, and hence analyses of the prospect samples are of limited use.

The topographic map used as a base for the geological mapping was the Blairmore topographic manuscript made in 1912 on a field scale of 4,000 feet to an inch with a contour interval of 100 feet. This was photographically enlarged and transferred to the township section grid plotted on a scale of 1 inch to 800 feet. Revisions of the culture, drainage, and topography found necessary were made in the course of field work. A geological structure model, comprising a series of seventeen geological structures crossing the area in an east-west direction at intervals of one-fourth mile, was constructed. As soon as all the data were compiled the International Coal and Coke Company was supplied with a hand-coloured geological map and a celluloid structure section model of their area at a nominal charge. Hand-coloured copies of the map can be obtained at a reasonable charge on application to the Director of the Geological Survey.

The writer desires to record his appreciation to the several officials of the International Coal and Coke Company, Mr. O. E. Whiteside, General Manager, Mr. J. A. McLeod, Mine Manager, and Mr. L. Lindoe, Engineer, for assistance given during the course of the investigations, for office and housing accommodation furnished, and for mine data and office material supplied. H. H. Beach and G. K. Lowther served as student assistants, and were entrusted with the map revision and the collecting of the greater amount of the field data.

STRATIGRAPHY

The International Coal and Coke Company coal area is underlain by Jurassic and Cretaceous sediments and a great thickness of Upper Cretaceous tuffs and breccias. The various strata involved, with their thicknesses as determined graphically from their width of outcrop and attitude of the beds, are as follows:

Formation		Thickness in feet	
		North	South
Upper Cretaceous...	Allison (Belly River)............................	1,800	....
	Alberta shale..................................	3,100	....
	Crowsnest volcanics............................	1,800	1,350
Lower Cretaceous...	Blairmore..	1,850	1,800
	Kootenay...	800	600
Jurassic............	Fernie..	60	....

Fernie Formation

The oldest strata exposed in the map-area form a small, elliptical outcrop about 1,250 feet long and having a maximum width of 150 feet in the channel of York Creek near the western border of Sec. 33, Tp. 7, Range 4. These beds are massive, dark shales with a few thin, dark sandstones and have an exposed thickness of 60 feet. Because of their lithological resemblance to the fossiliferous dark shales and thin sandstones of Jurassic age exposed in the old railroad cutting at the south end of Grassy Mountain, 6 miles to the northeast, these beds are believed to represent the uppermost beds of the same series. At Grassy Mountain the Fernie formation has a thickness of approximately 700 feet. The nearest measured section of the Fernie formation to the west of the map-area is that which occurs on Weaver Creek, 5 miles due west of Corbin. The thickness, as measured here by Mr. Leo Telfer, is 923 feet. The total thickness of the Fernie in Coleman area probably does not exceed 750 feet.

Kootenay Formation

Overlying conformably the so-called Fernie shales exposed on York Creek is a series of freshwater sediments which constitute the Kootenay formation. They consist of coarse, hard, grey-brown weathering sandstones, thin-bedded, fissile, grey and black shales, and several coal seams. The following composite section of the Kootenay formation near the mine entry gives the thicknesses of the coal seams and separating strata.

	Top of formation Feet
Rock interval..	22
Coal seam No. 1..	0–3
Rock interval..	30
Coal seam No. 2..	14½
Rock interval..	90
Coal seam No. 4..	7–10
Rock interval..	220
Coal seam No. 5..	17
Rock interval..	350
Approximate thickness of Kootenay formation....................	750

The section exposed in the channel of York Creek measured 584½ feet and is given in detail on page 45 of Summary Report 1932, Part B.

York Creek is the only locality within the map-area at which the top and base of the formation are exposed, but, owing to crushing and faulting, its thickness cannot be definitely determined. Its thickness in the Coleman North area was estimated as 800 feet and in the Coleman South area as 600. The Kootenay formation outcrops as a belt varying in width from 300 to 1,200 feet. It crosses Crowsnest River between Coleman and West Coleman and trends east of south to the southeastern corner of the map-area. It is bounded on the east throughout its entire length, except in the vicinity of York Creek, by a fault, and has a normal contact with the Blairmore formation on the west. Throughout the map-area it has an average dip of 34 degrees west.

The formation contains a maximum of five coal seams, only two of which are sufficiently thick and pure to be worth mining. These are seams Nos. 2 and 4. In the north they are separated by an interval of 90 feet, but southward this interval decreases markedly. The lowest seam, No. 5 seam, has been opened at several points, but so far has proved too dirty to mine. The remaining two coal seams, seams No. 1 and No. 3, are too thin to have much commercial importance.

No. 1 seam has been observed at only one locality, i.e. near the mine mouth on the south side of Crowsnest River. There, it is 3 feet thick and lies immediately beneath the massive conglomerate that forms the basal member of the Blairmore formation. It doubtless was originally far more extensive, but was largely removed by erosion prior to the deposition of the Blaimore conglomerate. Coal seam No. 3 ranges from 0 to 3 feet in thickness and where present lies about midway between seams Nos. 2 and 4. It is generally too high in ash to be of commercial grade and grades laterally into a carbonaceous shale.

Blairmore Formation

Overlying the Kootenay formation and separated from it by a prominent erosional unconformity is a thick series of freshwater sandstones, shales, and conglomerates. This series has a fairly uniform thickness over the map-area, being 1,850 feet thick at the northern end and 1,800 feet thick at the southern end. It outcrops as a broad band which varies in width with the topography and dip of the formation from 2,200 feet to 4,000 feet, and extends from the northwestern corner of the map-area to east of the centre of the map at the southern extremity. Throughout this distance the beds dip from 30 to 40 degrees west and have an average dip of 34 degrees west. In addition to the main outcrop, there is also in the fault zone a small, wedge-shaped block of Blairmore sediments, approximately ½ mile in length and 800 feet in maximum width, the centre of which lies 4,000 feet south of York Creek. The basal member of the Blairmore formation is a massive, hard conglomerate composed of pebbles of chert of various hues firmly cemented in a quartzite matrix. This bed averages 25 feet in thickness and forms the most easily traceable horizon in the area. Overlying the conglomerate are greenish and reddish weathering, sandy shales and light brown and dark greenish grey, coarse, soft sandstones, and at least one and probably several thin beds of brown weathering, green, freshwater limestone. Near the top of the formation there occurs a bed of conglomerate, ranging in places up to 12 feet in thickness, which is made up of waterworn pebbles up to 1 inch in diameter of chert, limestone, and igneous rocks, embedded in a brown-grey, sandy matrix. This conglomerate is overlain by greenish grey, coarse-grained, massive, crossbedded sandstones.

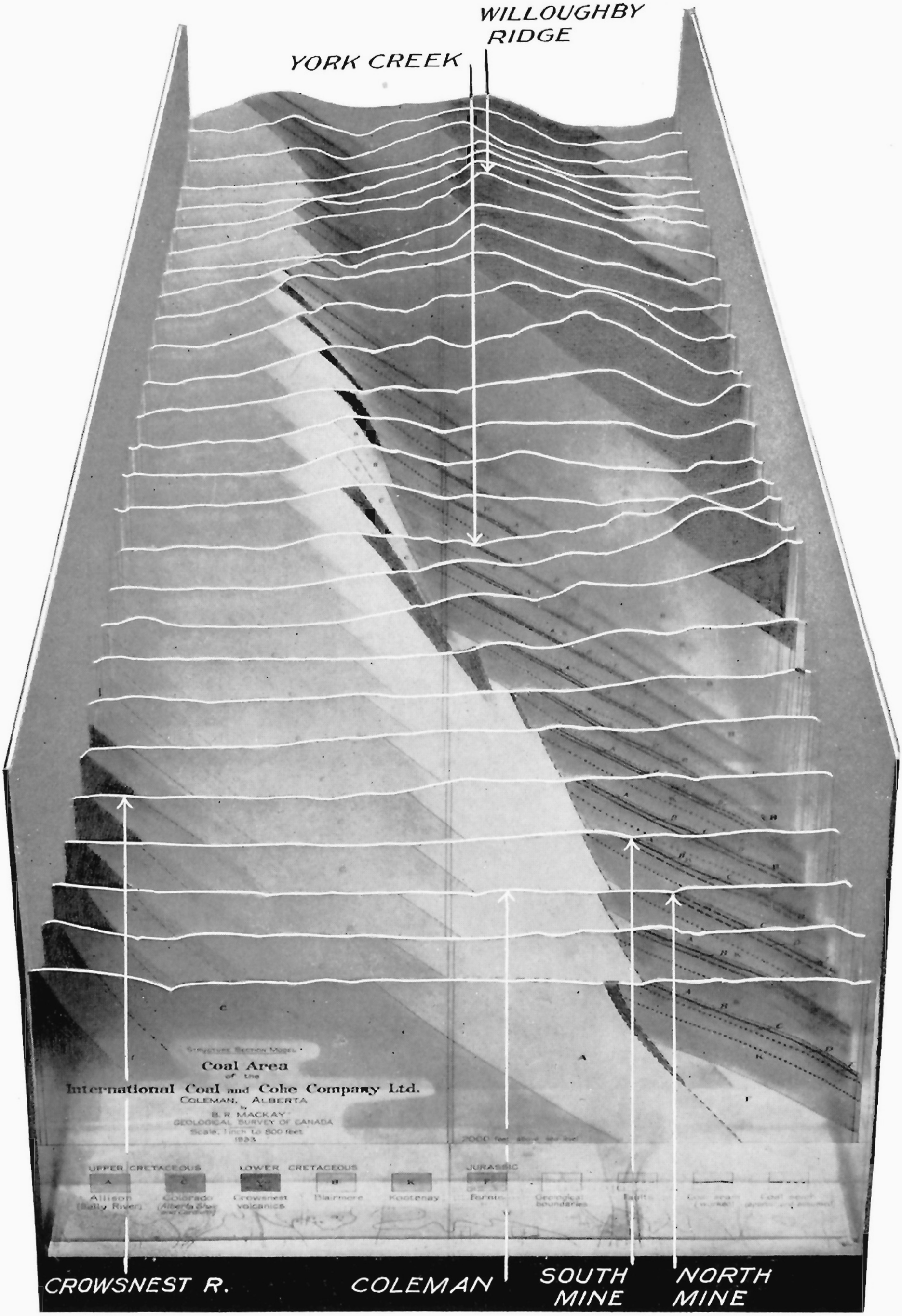
Crowsnest Volcanics

The uppermost, greenish grey, coarse-grained, massive, crossbedded sandstone of the Blairmore formation is overlain, without any apparent break, by waterlaid, thin-bedded, dark grey ash beds which grade upward into coarse, massive, olive-green tuffs with bombs up to a foot or more in diameter, followed by agglomerates and flow breccias interstratified with waterlaid ash. The tops of some of the flows are characterized by a profusion of phenocrysts of pink feldspar ranging up to dimensions of 1½ inches by ½ inch by ½ inch and others with large crystals of primary analcite. At some horizons, there are large, included fragments of a dark green rock having a uniformly textured groundmass with amygdules filled with analcite, leucite, and other zeolites. The volcanics have their greatest thickness of 1,800 feet in the northern part of the map-area and thin to 1,350 feet at the southern border. The flow rocks show in places distinct drag-folds, some of which may have been formed before consolidation of the material, but others, from the accompanying slickensiding and faulting, are undoubtedly of more recent date. In some of the massive beds the flow structure is entirely absent, the only structure apparent being that of vertical jointing and faulting. At certain places where the flows were observed to be interstratified with waterlaid, green, fine-grained ash, it was found that the inclination of the flow beds was as much as 10 degrees greater than that of the waterlaid sediment. The most plausible explanation of this is that the difference in dips represents the original slope of the tops of the flows and that the orifice from which the material was erupted lay to the east of the present main outcrop. In places the magnetite content of the volcanics is such as to seriously interfere with the using of the magnetic needle.

The Crowsnest volcanics form four outcrops in the map-area. The main outcrop crosses the western part of the map in a southeasterly direction, in a belt 3,200 to 4,500 feet in width. A narrow strip of steeply, westerly-dipping volcanics forms an eastern belt within the northeastern corner of the map-area, and in the fault zone are two wedge-shaped blocks of massive flows, each about 300 feet in width and 8,000 feet in length, and which have been dragged up between the Kootenay and Allison (Belly River) formations. The volcanics in the fault zone are greatly crushed and slickensided and the attitude of the beds is not apparent.

Alberta Formation

Overlying the Crowsnest volcanics is a great thickness of soft, dark, massive shales with thin, sandy beds, the fauna of which place them as being of Colorado age. The name Alberta has been assigned to these beds in Turner Valley area, and is here used. The existence of extensive concealed



Geological structure section model of Coleman South coal area, Crowsnest Pass, Alberta, looking south.

areas and the crushed nature of the beds prevent any measured section of the formation being obtained, but, from its width of outcrop and the average dip of the beds, the thickness in the Coleman South area is estimated at 3,100 feet. The formation outcrops as two belts; the eastern belt is 4,200 feet in width and is cut by the eastern border of the map-area, the other area occupies the southwestern corner of the map-area. A wedge-shaped block of the formation—300 feet wide and 5,000 feet long—occurs in the fault zone from York Creek south. A quartzite sandstone horizon, which probably represents the Cardium sandstone, of the northern area, outcrops in both of the main belts. In the eastern belt it lies 600 feet above the base of the formation, and in the western belt 250 feet above its base.

Allison (Belly River) Formation

The youngest sediments are soft, light-coloured sandstones and interbedded, freshwater, grey and black shales, containing a freshwater fauna. These beds constitute the lower part of the Allison (Belly River formation) and lie conformably upon the Alberta shales. They are cut off on the west by one or more, pronounced, south-southeasterly trending faults along which they are brought into contact with several of the underlying Cretaceous formations. The formation has its maximum width of outcrop of 3,000 feet and its maximum thickness of 1,800 feet at the northern end of the map-area and decreases gradually in width and thickness southward for a distance of 4¼ miles south of Crowsnest River to where it is cut out completely by the fault. The formation varies in dip from horizontal to 58 degrees west, its average dip being about 40 degrees west.

STRUCTURE

The Coleman South coal area with the exception of the fault zone is structurally simple (*See* Figure 4). It consists of a series of Mesozoic sediments and associated volcanic tuffs and breccias, having an average westerly dip of 35 degrees, which have been cut diagonally across the length of the map-area in a direction south 11 degrees east by one or more westerly dipping thrust faults trending parallel to the general strike of the formations. The beds on the west side of this fault zone have been thrust upward and eastward over those on the east with a vertical displacement of approximately 7,300 feet, thus bringing to the surface on the west side of the fault the coal deposits which normally would be 1½ miles beneath the surface.

The beds on the east side of the fault plane range from Crowsnest volcanics to Allison (Belly River) inclusive, and those on the west side from Fernie to Alberta shale inclusive. The fault zone crosses the northern boundary of the map-area just east of the centre line of Sec. 8, Tp. 8, Range 4, W. 5th Mer., trends south 11 degrees east, and 6½ miles distant crosses the southern end of the map-area, 1,000 feet from the eastern border of Sec. 9, Tp. 7, Range 4, W. 5th Mer. Over most of the length of the area the fault zone is narrow, with possibly a single fault, but for a distance of 3½ miles from the centre of Sec. 4, Tp. 8, Range 4, to the southern end of Sec. 21, Tp. 7, Range 4, the fault zone consists of from two to four or more faults which at the southern part of Sec. 33, Tp. 7, Range 4, are distributed over a width of 800 feet. The fault zone is made up of large, wedge-shaped areas of Crowsnest volcanics, Alberta shale, and Blairmore formation. The several wedges are fragments that have been dragged up along the fault planes, but, so far as could be determined, the strata composing the different wedges lie in their normal attitude. The inclination of the main fault plane is believed to increase in depth.

MINING DEVELOPMENT AND COAL DEPOSITS

The International Coal and Coke Company acquired the property in 1903, but it was not until 1905 that large-scale production began. Since that date the Dennison Colliery has been in almost continuous operation with two mines located on the north and south sides of Crowsnest River (*See* Figure 3). At each mine two coal seams, i.e. seams No. 2 and No. 4, are under development. The Upper or No. 2 seam is the thicker and the cleaner, and has accordingly received the greatest attention (Figure 4). The seams are mined mainly by means of separate entries, but the workings on the two seams are connected in depth by several tunnels, the lowest of which lies 550 feet below river level. In 1905 a battery of two hundred and sixteen coke ovens of the beehive type were erected and forty more were added in the year 1908. Up to date the colliery has produced about 7,000,000 tons of coal and slightly less than 750,000 tons of coke. The colliery is equipped with up-to-date machinery and a modern dry cleaning plant capable of sizing and cleaning 2,000 tons a shift prepares the product for the various market requirements. Compressed air locomotives haul the coal to the hoisting slope where a 700-horsepower winding engine raises it to the surface. The surface plant is almost completely electrified and electric pumps handle the necessary mine water.

The development work in North mine is mainly in No. 2 seam, which has been blocked out by slopes, levels, and rooms over the area extending from Crowsnest River north to the limit of the company's property at the northern boundary of Sec. 8, Tp. 8, Range 4, W. 5th Mer., a distance of 2,200 feet, and from the seam outcrop to the 5th or east level, 1,215 feet below the main haulage. Throughout the area the seam is remarkably uniform in composition, thickness, and attitude. It varies from 7 feet 2 inches to 10 feet in thickness and has a cap 10 to 12 inches thick of fine, hard shale and a shale floor. It dips from 27 degrees to 37 degrees west. The work done on No. 4 seam consists largely of the driving of a level and counter from a tunnel from No. 2 seam at B level (elevation 4,085 feet) and the driving of a pair of upraises, 700 feet up the dip to the outcrop. Over most of the distance this seam averages only 5 feet in thickness, and has a shale roof and false shale floor 5 feet thick.

At South mine, No. 2 seam has been developed for a distance of $2\frac{1}{2}$ miles south of Crowsnest River, the workings on A level or water-level gangway terminating 4,000 feet south of York Creek. To the north of York Creek the workings have been extended to near the outcrop and carried to the 4th or D level, which lies at a depth of 855 feet below A or main water-level. To the south of York Creek the seam was first opened up by a level and counter level driven in the seam from a point about 50 feet above creek-level. Later a slope was sunk on the seam and a lower level established. These workings were later connected with the C level workings carried southward from the main mine, and it is through this mine that all the coal south of York Creek

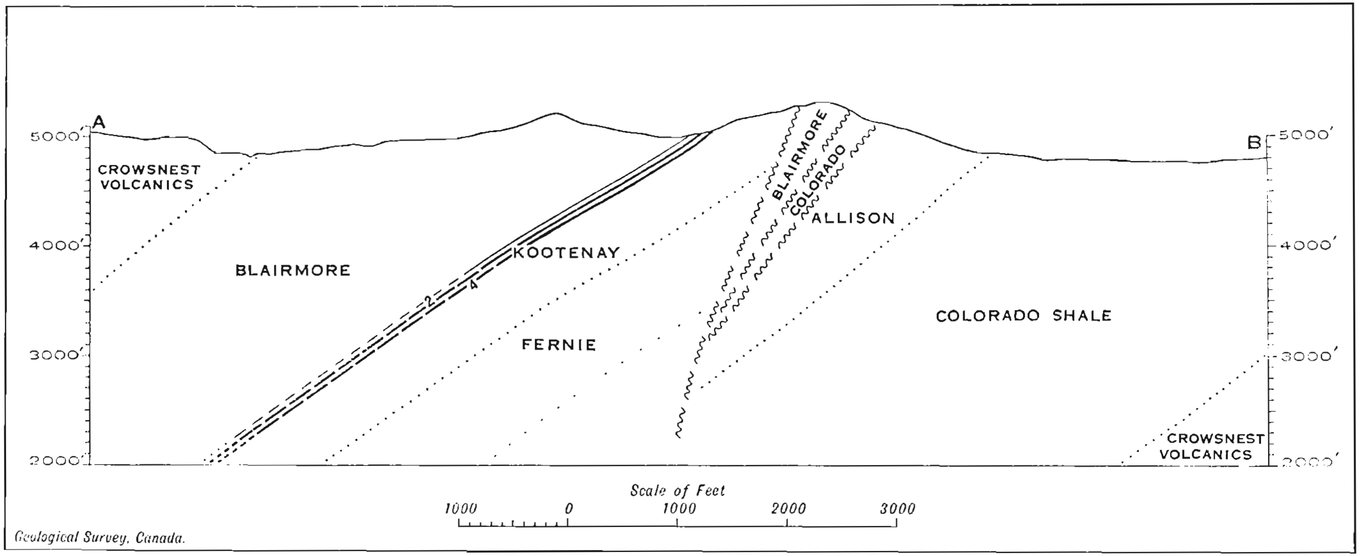


Figure 4. Structural section across Coleman South coal area showing coal seams being mined at Dennison Colliery by the International Coal and Coke Company (*See* Figure 3 for line of section AB).

is now being removed. The coal seam on C level at a point 1,200 feet north of York Creek, at No. 8 crosscut, south of No. 3 slope, measured 9 feet 11 inches in thickness; it has a cap of 15 inches of fine, sandy shale and dips 30 degrees west.

No. 4 seam in South mine was developed by a main haulage level run south for 9,000 feet, the end of the workings being about 1,500 feet south of York Creek. The workings were carried up the rise of the seam to as near the outcrop as it was deemed advisable to mine. At a point 1,600 feet from the mine mouth the main slope was driven down the dip of the seam. From this slope B and C levels have been driven to the south and to the north, and a large block of coal beneath the main water-level haulage has been blocked out by rooms and pillars.

Only one fault was encountered in the mine workings throughout the whole length of the property. This was a transverse normal fault which was encountered in South mine. It cuts the two coal seams at their outcrop approximately 700 feet south of the road allowance between Tp. 7 and Tp. 8, Range 4, W. 5th Mer., and trends north 102 degrees east. The beds on the south side of this fault have dropped slightly, resulting in an offset in the several levels of both mines of approximately 50 feet to the east of those on the north side of the break.

Coal seams No. 2 and No. 4, the two commercial seams of the series, have been traced throughout the whole length of the International Coal and Coke Company's property. In the northern part they lie from 110 to 90 feet stratigraphically apart. Traced southward, they gradually converge. The thickness and the position of these two seams with respect to the Blairmore conglomerate and to one another are indicated on the accompanying table. It will be noted there that the interval between the conglomerate and No. 2 seam varies from 50 feet to 80 feet, the thickness of No. 2 seam ranges from 4 feet to 16·9 feet, the thickness of No. 4 seam from 3 feet to 13·5 feet, and the interval between No. 2 and No. 4 seams varies from 90 feet at the north to 2·9 feet near the southern boundary of the company's holdings. The ten localities at which stratigraphic intervals are distributed over a length of 6 miles are arranged in order from south to north.

Table Showing Thicknesses and Positions of No. 2 and No. 4 Seams with Respect to the Blairmore Conglomerate and to One Another[1]

—	Prospect No. 4, 200 feet north of southern boundary Sec. 16	Prospect No. 5, 1,150 feet north of centre of Sec. 16	Prospect No. 2, 100 feet south of centre of Sec. 16	Prospect No. 1, 1,000 feet north of centre of Sec. 21	Prospect No. 3, 600 feet south of centre of Sec. 28	York Creek	1,300 feet south of north boundary of Sec. 33	South boundary of Sec. 8	Centre of Sec. 8	North boundary of Sec. 8
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
Blairmore conglomerate... Thickness....	25+	20+	30+	30	25+	25	25	25	25	25
Rock interval, partly concealed...	56·5	79·4	50	52·0	61·6	57	55	55	50[2]	50
No. 2 seam..........	13·0	15·5	16·9	4	9·5	9	9	10	11	10
Rock interval.......	3·5	2·9	5·0	19	22·4	47	50	70	100	90
No. 4 seam..........	13·5	7·0	6·1	9·6	8·2	4·10	5	7	10	10
Shale floor..........	....	....	....	....	4	....	....	....	....	....

[1] *See* Figure 3 for location of several prospect trenches.

[2] No. 1 seam observed only at centre of Section 8 where it is 3 feet thick and lies immediately beneath the Blairmore conglomerate.

The sections of the coal measures exposed in the five prospect trenches opened up in 1933 are as follows:

Prospect No. 4

Prospect located 200 feet north of southern boundary of Sec. 16, Tp. 7, Range 4, W. 5th Mer.

	Feet
Blairmore conglomerate	25+
Brownish weathering shale	1
Dull black, carbonaceous shale	4·5
Covered, probably sandstone	16
Mostly covered, but shale exposed in places	12
Shale, more carbonaceous towards base	22
Dirty coal	0·7
Shale	0·3
Coal, containing few small clay bands up to 1 inch thick in lower 5 feet (No. 2 seam)	13
Hard, fine-grained, greyish coloured shale	3·5
Coal (No. 4 seam), small shale stringers occur in lower 1½ feet	13·5
Carbonaceous shale	0·2
Clay floor	

Prospect No. 5

Prospect located 1,150 feet north of centre of Sec. 21, Tp. 7, Range 4, W. 5th Mer.

	Feet
Overlying conglomerate	20+
Covered	29
Thin-bedded, dark weathering, greyish black sandstone	16
Fine-grained, sandy shale becoming more argillaceous towards base	6
Shale, becoming more carbonaceous towards base	13
Thinly bedded, dark shaly, fine-grained sandstone interbedded with very thin beds $\frac{1}{8}$ inch to $\frac{1}{16}$ inch of carbonaceous shale	8
Shale with carbonaceous bands up to 2 inches	6·5
Dirty coal	0·9
Coal (No. 2 seam)	15·5
Sandy shale	1·5
Poor coal	0·5
Carbonaceous shale	0·9
Coal (No. 4 seam)	7
Carbonaceous shale—floor	

Prospect No. 2

Prospect located 100 feet south of centre of Sec. 21, Tp. 7, Range 4, W. 5th Mer.

	Feet
Overlying Blairmore conglomerate	30+
Covered material consisting of sandstone and carbonaceous shale	11
Shale, carbonaceous in places	5
Massive sandstone	1
Brown shale grading in places to carbonaceous shale	7
Carbonaceous shale, becoming thinner towards base	15
Dirty coal, with shale stringers and sulphur bands	11
Coal (No. 2 seam)	16·9
Shale	3
Sandy shale	1
Carbonaceous shale	1
Coal (No. 4 seam)	6·1
Coal, 2·4; carbonaceous shale, 0·2; coal, 0·2; shale, 0·4; coal, 3·1	

Prospect No. 1

Prospect located 1,000 feet north of centre of Sec. 21, Tp. 7, Range 4, W. 5th Mer.

	Feet
Overlying Blairmore conglomerate	30+
Covered, but likely sandstone or conglomerate	5
Sandstone, grading downwards into shale into carbonaceous shale	2
Coal—hard and high in ash	2·1
Carbonaceous shale	7·0
Covered, but probably sandstone	12·0
Black, thinly bedded, carbonaceous shale	24·0
Coal, No. 2 seam—high grade in appearance	3·8
Carbonaceous shale	5
Sandstone, brown weathering and coarse grained	9
Carbonaceous shale	5
Coal, No. 4 seam	9·6
Sandstone and shale	11
Coal, very poor	2·1
Carbonaceous shale	1·8
Coal	2·0
Shale floor	

Prospect No. 3

Prospect located 600 feet south of centre of Sec. 28, Tp. 7, Range 4, W. 5th Mer.

	Feet
Conglomerate	25+
Covered	14
Carbonaceous shale	7·5
Sandstone	6·0
Shale	10
Covered	3·5
Brown shale	3·0
Carbonaceous shale	3·5
Highly carbonaceous, black shale with small stringers dirty coal	3
Fairly clean coal	1·7
Dirty coal	1
Good coal	0·4
Brownish black shale with stringers of coal	2
Covered	3
Carbonaceous shale	3
Coal, No. 2 seam, clean coal, uniform throughout	9·5
Greyish shale	4
Brownish weathering sandstone	8
Dirty coal	1·9
Carbonaceous shale, grading downwards into sandstone	5
Bentonitic clay	0·5
Sandy shale	3
Coal, No. 4 seam (very uniform)	8·2
Shale	4

The increase in the thickness of the seams is accompanied by an increase in their ash content, due to the presence of thin clay partings in the seams and of pyrite balls and a higher percentage of disseminated pyrites in the coal. No. 2 seam, however, remains lower in ash than No. 4 seam throughout the areas. A representative analysis of the coal being mined at present in each of these seams is as follows:

—	No. 2 seam		No. 4 seam	
	As received	Dried	As received	Dried
Moisture	1·4	....	2·4	....
Vol. matter	25·7	26·1	22·3	22·4
Fixed carbon	58·8	59·6	27·0	58·4
Ash	14·0	14·2	18·3	18·7
S	0·5	0·5	0·5	0·5
Calories	6,360	6,450	6,570	6,730
B.T.U's	12,745	12,925	11,820	12,110
Fuel ratio	2·30	2·30	2·55	2·55
Coking properties	Good	Good	Good	Good

BUFF AND WHITE-BURNING CLAYS OF SOUTHERN SASKATCHEWAN

By F. H. McLearn (Geological Survey) *and J. F. McMahon* (Ceramics Division, Mines Branch)

CONTENTS

INTRODUCTION

The buff and white-burning clays of the Whitemud and Willowbunch beds are the most important of the mineral resources of southern Saskatchewan and form the basis of a ceramic industry. Some of the clays, particularly those of the Whitemud formation, have been used for the manufacture of fire-brick, sewer-pipe, art pottery, stoneware pottery, and face brick. Some have also proved satisfactory for use in the manufacture of white tableware and others have been used for the manufacture of sanitary ware, wall tile, and terra-cotta. For a number of years there has been a steady production of clay products at both Medicine Hat, Alberta, and Claybank, Saskatchewan. At the former locality, artware, stoneware, and sewer-pipe are made from Saskatchewan clays, and at the latter place fire-brick and face brick. At Medicine Hat the kilns are fired by natural gas and at Claybank by coal imported from Alberta.

These clays have been known for a long time. In 1885 McConnell noted a white band at the bottom of the "Laramie." In 1895 Hoffmann, chemist of the Geological Survey, Canada, examined a sample from the vicinity of Claybank, and recommended its suitability for fire-brick and pottery. In 1906 Chambers recorded the winter haulage of clay from the hills near Wood Mountain to Moose Jaw where it was being manufactured into common brick and some fire-brick. In 1907 Professor Edward Orton, jun., reported on samples from the Dirt Hills. Between 1912 and 1915 Ries and Keele published the results of extended sampling, measurements of deposits, and laboratory tests. Between 1914 and 1916 Rose recorded the results of some clay tests on samples collected by him. In 1916 Davis, in a valuable work, described the clays in very considerable detail. Later, Professor W. G. Worcester, working under provincial auspices at the University of Saskatchewan, has made many contributions. These have included sampling in the field, search for special clays, e.g. ball clays, and the devising of methods of treatment. Only a small part of his valuable work has been published. In 1930 G. M. Hutt described the fire-clays of southern Saskatchewan in an interesting paper. In 1932 McMahon summarized the economic possibilities of these clays.

FIELD WORK AND ACKNOWLEDGMENTS

Parts of five field seasons were given to study and sampling of the clay deposits by F. H. McLearn. About four weeks each were spent by J. F. McMahon and R. T. D. Wickenden in the field, in 1931. The following field assistants rendered efficient aid: O. L. Backman, W. A. H. Foulds, C. O. Hage, H. Johnson, E. I. Leith, A. Matheson, A. Pentland, and L. S. Russell. Consultations were held in the field with Professors W. G. Worcester and F. H. Edmunds of the University of Saskatchewan, and Professor P. S. Warren of the University of Alberta. Petrographic examinations and mechanical analyses of the sediments have been made by F. J. Fraser in the laboratory. All elutriation tests cited are by him. Ceramic tests have been made by J. G. Phillips and J. F. McMahon. Important advice in the preparation of the report has been given by Howells Frechette, Chief of the Ceramics Division, Mines Branch.

GEOLOGICAL OCCURRENCE

The white and buff-burning clays of southern Saskatchewan occur at two levels, in the Whitemud formation and in the Willowbunch member. The Whitemud is of late Cretaceous age. The Willowbunch is of early Tertiary, Paleocene age, and is high in the Ravenscrag formation. It is more than 400 feet above the Whitemud formation, as the following table shows:

			Formations		Feet	Lithology	Clay beds
Cenozoic	Tertiary	Miocene	Wood Mountain		50±	Gravels, sands	
		Oligocene	Cypress Hills		200+	Gravels, sands	
		Eocene	Swift Current		50	Gravels, sands	
		Paleocene	Ravenscrag	Upper	100+	Non-marine sands, shales, coal seams	
				Upper: Willowbunch member		Non-marine sands, sandy clays, shales, clays	White and buff-burning clays
				Upper	420	Non-marine sands, shales, coal seams	
Mesozoic	Cretaceous	Upper Cretaceous		Lower	20–190	Non-marine sands, shales	
			Whitemud		12–75	Non-marine sands, sandy clays, shales, clays	White and buff-burning clays
			Eastend		20–100	Marine and non-marine silts, fine sands, shales	
			Bearpaw			Marine shales, fine sands	

A problematical zone, that of Sand E, comes between the Eastend and Whitemud beds at eastern localities, as at Willows.

Before describing the Whitemud and Willowbunch zones, attention may be called to other important clay deposits in Canada and their relative ages. In central Alberta, on Red Deer River, a zone of light grey clays, high in the Cretaceous Edmonton formation, has been tentatively correlated with the Whitemud. At Sumas Mountain, B.C., are high-grade clays which are of early Tertiary age and possibly of Eocene date. North of McMurray in places are clays between the Devonian and the Lower Cretaceous McMurray formation. They are of a much earlier age than the Whitemud or Willowbunch and of not later than early Lower Cretaceous time. In northern Ontario the clays of the Mattagami series are also of much earlier age than the Saskatchewan deposits and of late Jurassic or early Lower Cretaceous time. In Musquodoboit and Shubenacadie Valleys, Nova Scotia, are similar deposits which have been tentatively dated Lower Cretaceous, but their exact age is problematical. The relative ages of these deposits are indicated in the following table:

			Clay-burn, B.C.	Lower part Atha-baska River	Red Deer River	Saskat-chewan	Mon-tana	North-eastern Mon-tana	Northern Ontario	Nova Scotia
Cenozoic	Tertiary	Eocene	Deposits of Sumas Mountain							
		Paleocene				Willow-bunch		Willow-bunch?		
Mesozoic	Cretaceous	Upper Cretaceous			Clay zone near top Edmon-ton	White-mud	Colgate			
		Lower Cretaceous		Deposits north of Mc-Murray?					Mattagami	Beds of Shuben-acadie Valley?

The dark marine shales of the Bearpaw formation, which contain in some places well-preserved marine shells, were the last purely marine sediments deposited on the site of the Canadian plains. The overlying yellowish, brownish, and grey, very fine sands, silts, and shales of the Eastend formation are apparently partly marine and partly non-marine and are transitional to the Whitemud formation. By Whitemud time there is abundant evidence, including the occurrence of fossil roots and leaves, that non-marine conditions had become fully established and that from Whitemud time to the present no sea has flooded the site of the Canadian Great Plains. For a non-marine formation the Whitemud occupies, or rather once occupied, a fairly large area. From the type area on Frenchman (Whitemud) River near the east end of Cypress Hills it can be traced, with some discontinuity, to the west end of Cypress Hills in southeastern Alberta. It can also be traced eastward at least as far as Big Muddy Valley and Claybank, and possibly even to Souris Valley. If the Colgate sand, in Montana, is a continuation of the Whitemud it can be traced far to the south. Its economic value there has not been established, however. The distribution of the Whitemud in southernmost Saskatchewan is shown on the Regina map-sheet (in course of preparation for publication). The conditions controlling this distribution are described later. Although the Whitemud formation is widely spread it is marked by local changes that undoubtedly affect its commercial value. Therefore, it is advisable to examine the internal structure of the formation and its variations.

The Whitemud has typically four zones:

(4) Dark shale zone
(3) White clay zone
(2) Brown shale zone
(1) White, sandy clay zone

At some localities one or more zones are absent. Only the first and third are of commercial value. The White sandy clay zone consists principally of thick beds of white or light grey weathering, light grey refractory and semi-refractory, sandy clays. These consist of grains of quartz, feldspar, and black to grey argillite or chert, with white clay in the matrix. Mica is also present. The percentage of clay in the sandy clay varies from place to place, is in places higher than 50 per cent, and is more or less related to the degree of refractoriness. Beds of fine silt, shale, or clay occur in this zone, in places. They are mostly non-refractory or only semi-refractory, and where they are present in considerable amount, the sandy clays interbedded with them tend to be low in percentage of clay and refractoriness. Rarely the entire sandy clay zone passes over into non-refractory brown and dark grey shales. In places, also, the massive, sandy clay passes laterally into non-refractory, sandy clays low in percentage of clay, or even into grey sand without appreciable clay contents. This seems to occur where the overlying Brown shale zone is particularly thick. In places the sandy clay of the White sandy clay zone decreases in percentage of clay and refractoriness downward. The shales and clays of the Brown shale zone are mostly brown or grey in colour, partly carbonaceous, and mostly non-refractory. The White clay zone includes mostly refractory and semi-refractory clays, silts, and sandy clays, which occur in beds a few inches to 5 or more feet thick. The colours are mostly white or pale shades of grey, purplish, mauve, brownish, etc. Each bed differs from the others in colour, grain, degree of refractoriness, and other ceramic qualities. There is no uniform change vertically, but in many places the most refractory clays are at or near the top of this zone. Some clays contain minute, ferruginous spherules. Clay ironstone nodules also occur in places. Although locally individual beds have considerable persistence, lateral changes take place. The clays change in ceramic properties and in grade, i.e., in grain. Clays may be replaced laterally by silt or sandy clay beds may wedge in or out. The uppermost and Dark shale zone contains dark grey, non-refractory clays and silts and has no material of ceramic value. It is only included in the formation because an unconformity is present above it and the unconformity is accepted as the upper limit of the formation.

The above-described, internal structure of the Whitemud formation may be better understood if a theory of origin of the formation and its refractory clays is explained. The sediments of the Whitemud formation, in common with other Cretaceous and early Tertiary sediments, are thought to have come mostly from an old land-mass west of the present Rocky Mountains, to have been transported to the present site of the Great Plains by streams, and deposited there on what was then an alluvial plain. That the weathering on this old land-mass was mainly mechanical and that there was little chemical weathering during transportation is demonstrated by the abundance of feldspar in the sands. In Whitemud time the Whitemud sediments were weathered after deposition and more or less contemporaneously, i.e., layer by layer or zone by zone, or one layer or zone before the deposition of the next. The alteration probably took place during temporary falls of the water table on the old flood-plain, which created a zone of weathering. The alteration was produced by downward seeping waters charged with organic acids produced by decay of surface vegetation. At least a warm temperate climate is necessary and considerable time. In the sandy clay zone the leaching action of the downward seeping water altered the feldspar grains in part to kaolin which coated the feldspar grains and filled the matrices between the grains. So the original feldspathic sands became sandy clays or *kaolinized feldspathic sands.* The percentage of clay so produced in the sandy clay varied greatly and was higher than 50 per cent in places. As the clay is the refractory ingredient in the sandy clay it is not difficult to understand that the sandy clays high in clay contents tend to be the most refractory. Where the fine sediments of the overlying Brown shale zone are particularly thick they seem to have blanketed the sands below and impeded the downward seepage of leaching water, and have retarded or completely prevented the alteration of the feldspathic sands. This seems to be the best explanation of the little alteration of the sands of the sandy clay zone north of the town of Eastend. It is possible that at this locality little alteration had taken place before sufficient fine sediments of the Brown shale zone had accumulated to exert a blanketing effect and prevent further alteration. The presence, in places, of numerous beds of shale, fine silt, or clay in the sandy clay zone also seems to have at least retarded alteration. Moreover, these fine sediments, where they occur in the sandy clay zone, seem to have suffered only partial alteration themselves; probably due to their fine grain and the lack of time for the alteration of such fine sediments. Their alteration would take much longer than that of the sands, for they are more impermeable to leaching waters. The most thorough leaching and alteration of the sandy clay zone seems to have been where there was no blanketing by a thick Brown shale zone and where interbedded clay and fine silt beds did not impede downward seepage of surface water. The decrease downward in many deposits of the percentage of clay in the sandy clay supports the theory of alteration by downward seeping waters. The sediments of the Brown shale zone have obviously been little altered since deposition. Their fine grain and possibly also too rapid deposition may account for this. Slow deposition and prolonged exposure to weathering alone would make possible the alteration of such sediments. This brings us to the problem of the origin of the White clay zone. It contains some very fine sediments which are highly refractory and have evidently undergone very considerable alteration. It may have been that accumulation was very slow or even completely suspended at times, so that alteration of individual layers before burial by the succeeding layer was possible. Such more or less contemporaneous weathering, bed by bed, might explain the different ceramic qualities of successive beds, as the leaching of one bed might not be of the same order as another, due to different length of time of exposure at the surface, different degree of permeability of the sediment, etc. Another hypothesis, already proposed, is that the clays of this zone are due to reworking of sandy clays formed by the weathering of feldspathic sands. The clay might have been re-sorted and redeposited to form beds of clay and the sand residue redeposited to form a new feldspathic sand layer, which by further weathering would produce a sandy clay layer. Difference in successive layers might be explained by variable admixture with incoming extra-regional and unaltered clay. Possibly both penecontemporaneous slow weathering of fine sediments and reworking of feldspathic sandy clays played a part in the origin of the clays of the White clay zone. The sandy clays and silts of the White clay zone, most common in Eastend area, are probably, like those in the sandy clay zone, the result of weathering of feldspathic sands and silts in place after deposition. Lateral variation in ceramic qualities of clay beds may be due to unequal weathering at different places because of different time of exposure at the surface before burial, to different groundwater conditions, etc. The presence of the highest grade and the most altered clays at or near the top of the White clay zone may point to longer exposure of these beds at the surface, to greater reworking, or less contamination by incoming unaltered sediment from the old land-mass in the west. The fine sediments of the Dark shale zone are not altered, possibly because of too rapid deposition and unfavourable groundwater level and climatic conditions.

An interval of erosion that followed the deposition of the Whitemud beds is of very considerable economic importance, because in that interval large areas of the formation were completely removed so that the overlying Ravenscrag formation came to lie on the Eastend or Bearpaw formations. In other places only parts of the Whitemud were removed, so that there the Ravenscrag formation came to lie on either the Brown shale or White sandy clay zone. Where even merely the White clay zone was removed, however, considerable damage was done, for the best plastic clays are in this zone. Further details will be given under descriptions by localities.

The second important clay zone, that of the Willowbunch member, lies high in the Ravenscrag formation. The Lower Ravenscrag immediately overlies the Whitemud, is very variable in thickness, is thickest where the Whitemud was most removed in the erosional interval and thinnest where it was least removed. The sediments of the Lower Ravenscrag levelled off the irregularities left by the pre-Ravenscrag erosion. The Upper Ravenscrag differs from the Lower in the presence of numerous coal seams. Over much of southernmost Saskatchewan it can be divided into two facies, a lower grey and an upper cream or buff. The Willowbunch member lies high in the buff facies, about 420 feet above the base of the Upper Ravenscrag. It is not so continuous as, and is much more variable than, the Whitemud formation, and in places is difficult to identify. It is, therefore, more difficult to trace, and all zones referred to it may not be at exactly the same horizon. In places there seem to be two zones about 40 feet apart. The upper of the two is assumed to be the true Willowbunch. On the whole the material is not so refractory as that of the Whitemud, but locally there is clay of good grade. Sandy clay has only been found in a few places, and where present is at the base of the zone as in the Whitemud formation. The clays resemble those of the Whitemud in appearance. A mottled clay, possibly the result of the filling of rootlets by dark grey clay, is rather characteristic of this zone although not everywhere present. The origin is probably the same as that of the Whitemud. Details are given under localities.

The Whitemud beds were not only subject to erosion in the pre-Ravenscrag interval, but to later erosion as well, for clay deposits of both zones were destroyed by erosion in Tertiary and Recent time. In Jurassic, Cretaceous, and early Tertiary, i.e. Paleocene time, the site of the Great Plains was an area of deposition, of a great sinking trough in which thousands of feet of sediments, including those described above, accumulated. But after Paleocene and throughout most of Tertiary time there was broad uplift and erosion and the present plains were gradually carved out of the basement of sediments which had piled up in the great trough. In the course of this erosion much of the later and uppermost sediments were destroyed. Thus the Whitemud and Ravenscrag, with its Willowbunch member, were removed from all but certain areas favourable to preservation in the southern part of Saskatchewan. This is why the Whitemud and Ravenscrag formations are now confined to the old and high watershed between the ancient Missouri and Saskatchewan drainage basins, including the high Cypress Hills, Frenchman River, Wood Mountain, and Big Muddy uplands, to the high Coteau, and possibly also to the synclinal basin along Souris River.

WINNING

Open pit or quarrying methods have been used mostly, underground operations very little. At many localities, however, the overburden is too thick for open pit methods. Operations have so far been confined almost entirely to deposits with light overburden.

In the location and planning of open pit work, many factors must be considered. The quarry site should be studied. The nature and variations of the deposit should be examined in natural exposures, pits, trenches, and auger-hole sections. The vertical zoning and lateral variations described above must be carefully investigated. The suitability of the clays, singly or in combination, for the manufacture of the desired products, must be determined by sampling and testing. The Dark shale zone, of course, will be removed with the overburden. In the working of the White clay zone, the variations, bed by bed, must be examined. If special clays are required the bed or beds containing them should be located by sampling and worked on a separate bench or benches. Fortunately at many localities the highest grade clay is at the top of the zone, so that it can be removed on a separate bench without removing the remaining and underlying beds. If the latter are needed for other products or for mixing with higher grades they can be worked on lower benches. At some localities, and for some purposes, all or the greater part of the clay zone can be worked on one bench. If plastic clay only is desired the coming in of beds of sandy clay or silt should be looked for and considered in the planning of a quarry site. If the sandy clay is to be rejected to the dump, its presence in this zone will add to the cost of working. Should, however, the sandy clay be desired as well as the plastic clay, the sandy clay can be removed on a separate bench. Working by several benches, however, will add to the cost of quarrying. The thickness and persistence of the bed or beds of desired clay should be determined as far as possible. The thicker the bed, presumably the cheaper the cost of winning will be and the greater the thickness of overburden that can be removed. The more persistent the bed, the greater the expansion and life of the quarry will be providing the amount of the overburden permits such expansion. In the study of the quarry site the contact between the Ravenscrag and Whitemud should be examined and it should be determined whether or not descent of the contact will cut off the clays of the clay zone and so limit the expansion of the proposed quarry in one or more directions. Descent of the contact is in many places marked by thick greenish grey sand with hard ledges of sandstone, which take the place of the Whitemud beds that have been removed.

As the Brown shale zone has chiefly clay of low grade it will be worked in few places.

Where sandy clay is required it may be worked on a lower bench after the overlying clay zone has been quarried, or, if the clay zone is not worth working, after it has been removed with the overburden. The tendency of the percentage of clay in the sandy clay to decrease downward toward the base of the sandy clay zone must be taken into consideration. It must be noted whether silt or clay zones are present and whether in any direction the sandy clay tends to pass into unleached and unaltered grey sand.

With modifications the above remarks apply also to the Willowbunch member. It is, however, a more variable zone than the Whitemud.

CLASSIFICATION OF CLAYS

Clays are composed of hydrous alumina silicates which become plastic when wet, hard when dried, and durable when burned to a sufficiently high temperature. They may be classified as follows:

White-burning	Refractory	Open burning (china clays)
		Tight burning (ball clays)
	Non-refractory	Limy brick clays
Buff-burning	Refractory	Open burning (fireclays)
		Tight burning (fireclays-ball clays)
	Non-refractory	Long range (sewer-pipe-stoneware)
		Short range (limy brick clays)
Red-burning	Non-refractory	Long range (sewer-pipe, roofing tile)
		Short range (brick clays)

Clays vary also in working and drying properties. All of these properties must be known in order to determine what classes of ceramic products can be manufactured from a given clay.

There was a time when only a single clay was used to produce an article, but today, even in the manufacture of some building brick, the blending of raw clays is practised. At one time it could correctly be assumed that any given article would be made in some one way, but today this is not so. New processes have been invented and some hitherto condemned clays are now utilized. So today, in order to recommend a clay as an ingredient in the manufacture of any specific product, it is necessary to know not only its individual properties, but also its behaviour when blended with other clays and its adaptability to various processes.

It is not possible to describe in detail all the properties of each of the numerous Saskatchewan clays tested. Instead a classification of the clays is proposed and each tested clay is assigned to a numbered type in that classification. An explanation of the terms used as a basis for this classification follows.

Water of Plasticity. The percentage of water added to the dry clay to develop best working properties.

Working Properties. The ease with which the wet clay can be shaped and the manner in which the shape is held.

Drying and Dried Properties. The percentage of linear drying shrinkage based on the wet length, the tendency of the clay to crack during drying, and the tendency to form a drier scum.

Burning and Burned Properties. The percentage of linear shrinkage when burned to various temperatures calculated on the wet length. The colour and the hardness of the resulting products together with their absorptions (per cent of water held when the burned product is saturated).

P.C.E. (Pyrometric cone equivalent). The number of the standard cone that indicated the temperature at which a tetrahedral-shaped specimen of definite dimensions, when heated at a definite rate in an oxidizing atmosphere, softened so as to bend and touch the plaque on which it was set.

Classification of the Clays in the Whitemud and Willowbunch Formations

				Type No.
I. Plastic	A. White-burning	P.C.E., 28–33	Clean	(1)
			Iron-spotted	(2)
			Very iron-spotted	(3)
	B. Buff-burning	Absorption greater than 4% at cone 6	Clean	(4)
			Iron-spotted	(5)
			Very iron-spotted	(6)
		Absorption 4% or less at cone 6		(7)
II. Short	White and buff-burning	P.C.E., from 28 to 33		(8)
		P.C.E., from 20 to 27		(9)
		P.C.E., below 20		(10)

Group I: Plastic. This group contains the materials highest in clay substance and that are the most important to the existing ceramic industry. Their value is due not only to their plasticity, but also to their dry strength, burning properties, and refractoriness.

Subdivision A: White-burning. This subdivision includes those clays that give most indications of being serviceable in the manufacture of refractories and also those that may prove valuable as bond clays for the manufacture of whitewares or pottery in general.

Type (1). This type includes those clays that are most promising for use as bond clays in the whiteware industry.

Type (2). Certain clays of this type might be used as bond clays in the manufacture of whitewares, but the iron concretions would have to be removed. This type could be used to good advantage in the manufacture of refractories.

Type (3). This type because of the high content of iron concretions is not recommended for use as a whiteware bond clay. Clays of this type could be used to advantage in the manufacture of refractories.

Subdivision B: Buff-burning. This subdivision includes those clays suitable for the production of general pottery lines. Some are sufficiently refractory to be used in the production of firebrick.

Type (4). Clays of this type could be used as bond clays in the manufacture of whiteware, terra-cotta, sanitary ware, etc.

Type (5). Certain clays of this type might be used for purposes mentioned under type (4), but only after the removal of their iron concretions.

Type (6). The uses of clays of this type are limited to the manufacture of coarse pottery or cheaper grades of clay products.

Type (7). The clays of this type are suited to the production of stoneware pottery, sewer-pipe, and general medium-priced, vitrified products.

Group II: Short. This group includes those clays heretofore called sandy clays. Due to their low clay content, their general working properties are poor. They might, however, be moulded in the dry or semi-wet state. The percentages of clay substance in clays of this type vary from 10 to 53 per cent. The refractoriness of these short clays tends to increase with the per cent of clay substance. Untreated they have no particular value. Treated by washing, however, they may be of value as a possible source of kaolin. It is understood that some experiments have been made in Saskatchewan, but no information is available at present.

Type (8). Clays of this type contain from 35 to 50 per cent of clay substance. Their P.C.E. values suggest their suitability for the manufacture of refractories. However, this is not true of all these clays because of a high percentage of quartz in the sand and silt grades. The amount of quartz present is apt to give a poor spalling-resistant brick. Treated by washing the clay may prove to be a source of kaolin.

Type (9). Clays of this type contain from 27 to 55 per cent of clay substance, the majority from 30 to 40 per cent.

Type (10). These clays contain 10 to 51 per cent of clay substance, the majority from 20 to 35.

Classification of Clays Tested

([1] Not in a continuous section; Ind., presence indicated but not established; N.C.T., not comprehensively tested; N.T., not tested.)

Table No.	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	General remarks
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	
1											Low refractoriness
2	5 6			2 7			7 5[1]			12+	Good section
3							1 0			Ind.	Tests show poor material
4		2		1 7		8	1 5			28	Considerable N.T.
5							4			1 8	
6											Tests indicate clays of poor quality
7							8 [1]		3		Fair exposure type (7)
8							8 3[1]				Separated by sandy clays, N.T.
9							4				
10							2 10[1]				Considerable silt and silty clay, N.T.
11											Poor indications
12			9 3				7 0	1 3			Good section
13							3 Ind.				Poor section
14	2 8						1 7		12 7		Sandy types predominate
15	1 8						5 7		2 7	3	
16			Ind.	2 6			10 0		Ind.	5	
17							4 3[1]				Parts not tested
18							4 4				N.C.T.
19							2 3				Poor showing
20				Ind?	Ind?		Ind.		Ind.		Separation not definite
21				5 8			6 6				Good showing
22	4 3						3 5[1]		9 9	3 3	Silty clays, N.T.
23				1 11					Ind.		N.C.T.
24		Ind.		Ind.		Ind.				Ind.	N.C.T.
25							2 8		30[1] Ind.		Sandy clays predominate
26											Not good showing

27											Not good showing
28	3 9	8 10						4 8			Good showing
29		19 2¹						6			Good showing
30		1 7 Ind.		5 6 Ind.				8	8 5		Fair showing
31		11 8¹									Irony layers between
32	Ind.	Ind.						2			Ind. of 9 ft. of (1) or (2)
33											Poor showing
34					3 9	Ind.	1 7		4 0		Fair showing
35		1 10							12 4		Sandy clays predominate
36				Ind.			Ind.		Ind.		Sandy clays in between
37		6 4		3 7					4 10		Good showing
38											No clay of economic value tested
39									Ind.		9 ft. 5 ins. sandy
40						16 9					
41	7 ¹	8 ¹		6 8¹					4 2¹Ind.		Good showing
42	6	3 2									Fair showing
43				2 0					14 8	7 8	Sandy clays predominate
44	8 ¹	8 ¹	2 8	1 1		2 6			6 8¹		Good showing
45		3 11¹	1 0	1 0		5			5 6		Good showing
46		8	2 9	3 6				3 5			Good showing
47				3							
48	3 ¹		8	7 4				1 4	6 2		Good showing
49	Ind.	Ind.									Heavy overburden
50		9		5 1		4 0			16 4		Heavy overburden
51						8 Ind.			8 8	2 2	Heavy overburden
52	Ind.	Ind.									N.C.T.
53	2 7										Heavy overburden
54		9	2 ¹	8	2 10¹	1 9			6 2	5 8	Fair showing
55				3 8	4 9				4 10¹		10 ft. plastic clay, N.T.
56	1										Very heavy overburden
57		1									Very heavy overburden
	Ind.			Willowbunch Member							
58	3 10			1 4 Ind.			2 3		5 6		Poor clays above
59				3 4							Poor clays above
60	6 6										Fair showing
61	3 8					1 9			5 3¹		Fair section
62		3			2 9		2 10				Fair section
63											No good clays in this section
64			2 10	10 2		2					Good showing
65				4 Ind.					13		Sandy clay predominates
66	1 8	2 10		16 9Ind.¹					5 0	6	Good showing
67				1 7			1 11				Poor showing
68											Poor showing
69	Ind.										Poor showing
70					3	4			4 7		Fair showing

Classification of Clays Tested—Concluded

([1] Not in a continuous section; Ind., presence indicated but not established; N.C.T., not comprehensively tested; N.T., not tested.)

Table No.	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	General remarks
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	
71				2 0	14 8		1 7		5		Good showing
72					5 7[1]		6 2[1]				Good showing
73	Ind.	Ind.									6 ft. 3 ins. of (1) or (2)
74				3 6 Ind.		4 11[1]Ind.					N.C.T.
75	6 Ind.			8 10							Sandy clays on top
76											Indications poor
77							5 0				Fair showing
78				Yes							No depth given
79				2 Ind.							
80							Ind.				
81						8 4					Fair showing
82					2 8		6				Poor showing
83						1					Poor showing
84	11			1 2							Poor showing
85							2 0		2 0		Poor showing
86				1 10		3 0					Fair showing
87											Clays of little economic value
88											Clays of little economic value
89											Clays of little economic value
90											Clays of little economic value

COMMERCIAL CLASSIFICATION OF CLAYS

The Whitemud and Willowbunch clays when considered according to the uses that may be made of them in the manufacture of clay products may be grouped as ball clays, refractories, clays for general pottery purposes, and clays for the manufacture of vitrified products.

Ball Clays. Those clays that have high plasticity, high refractoriness, and burn to a white colour are, in this report, considered ball clays. They occur mostly at the top of the Whitemud formation and, where examined, are in beds not thicker than 19 feet. Practically all crack when dried and vary in the amount of extraneous materials that they carry. Due to their cracking tendency they canot be used alone. They are ideal bond clays and are important from this point of view.

For clays of this class *See* Tables *2*, 14, 15, 22, 28, 29, 30, 31, 32, 35, 37, *41*, *42*, *44*, *45*, *46*, *48*, 49, *50*, 52, *53*, 54, 56, 57, 58, 60, 61, 62, 66, 69, 73, 75, 84. The numbers in italics indicate the tables dealing with clays that seem of greater importance.

W. G. Worcester in his paper[1] on the ball clays of Saskatchewan has treated this class of clays in a very comprehensive fashion. In his selection of ball clays, are clays whose natural colours are white, grey, blue, purple, chocolate, and black. Some he describes as plastic, others as gritty. The percentage of clay in his selected ball clays varies from 53·1 to 88·7 per cent (majority in the neighbourhood of 80 per cent). All his other tests are on washed samples. It should be noted that he states that all the clays tested by him contained some " iron-bearing mineral " which caused a more or less spotty appearance when the clays were burned to cone 8. Five of the clays described by him are at present being used in the production of whitewares.

L. P. Collin[2] in a paper dealing with methods of determining the dry strength of ball clays, included the results of tests on certain clays from Saskatchewan.

Clays for the Manufacture of Refractories. Sufficient work has not yet been done to permit making definite statements regarding the employment of the clays of southern Saskatchewan in the manufacture of refractories. Clay types (1), (2), and (3) have high degrees of refractoriness, but their drying properties are such as would limit the percentage of raw clay that might be used in a mix. The clays of Group II, particularly those of type (8), although highly refractory contain such high percentages of quartz as might cause trouble.

The above remarks relate to the use of the clays unmixed. The good results obtained by a manufacturer who is at present producing refractories from clays of this area by careful selection and preparation indicate to what extent they will be of ultimate value.

For clays having high P.C.E. values of 29 and greater *See* Tables *2*, 4, 12, 14, 15, 16, 20, 21, 22, 24, *28*, 29, 30, 31, 32, 35, 37, 41, 42, 44, 45, 46, 48, 49, 50, 51, 52, 53, 54, 56, 57, 61, 62, 69, 73, 77, 79, 81, 84. The numbers in italics are of tables relating to thick deposits.

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[1]Investigation of Twenty-one Saskatchewan Ball Clays; Jour. Am. Cer. Soc., vol. 12, 1929, p. 360.

[2] Transverse Strength of Ball Clay-sand and Ball Clay-flint mixtures; Investigations in Ceramics and Road Materials, 1928-29; Mines Branch, Dept. of Mines, Canada.

Clays for General Pottery Purposes (Types (4), (5), and (6)). These are all buff-burning; a number of them crack in drying, others show no signs of drying cracks. Some burn very clean, whereas others produce iron-spotted bodies. All show good working properties and have an absorption greater than 4 per cent at cone 6. The per cent of clay substance varies from 40 to 100 per cent, the greater number containing from 70 to 100 per cent.

For clays of this type *See* Tables 2, 4, *16*, *20*, 21, 23, *24*, 30, *34*, *36*, *40*, 44, 50, 51, 54, *55*, *61*, *62*, *64*, 66, 67, 70, 71, 72, *74*, 75, 78, 79, *80*, 81, 82, 83, 84, 86. The numbers in italics are of tables relating to clays that crack in drying.

Clays Suitable for Use in the Manufacture of Vitrified Products (Type (7)). All these clays are plastic, exhibit good drying properties, burn to buff colours up to cone 4 and to grey at cone 6, and are vitrified at cone 6. Their P.C.E. varies from cone 10 to 26; the average P.C.E. of most lies between cones 15 and 19. Their linear drying shrinkage varies from 5·8 to 11 per cent, but of most is in the neighbourhood of 7 per cent. All are good working clays and though some crack in drying, most of them possess good drying properties. At cone 2 they show a linear fire shrinkage of approximately 5 per cent and an absorption of 6 per cent (a number are vitrified at this temperature). At cone 4 the linear fire shrinkage is about the same as at cone 2, though the absorption drops to 3 per cent in the more open ones and is negligible in a great number of them. At cone 6 the linear fire shrinkage increases to 7 per cent and all bodies are vitrified. Their burned colours vary from cream to buff to grey. Some give good, clean colours but others are spotty or dirty.

For clays of this type *See* Tables 2, 3, 4, 5, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 25, 34, 36, 58, 62, 67, 71, 72, 77, 80, 82, 85.

DESCRIPTIONS OF OCCURRENCES

As at most localities only a single section has been sampled, nothing more than the mere possibilities of each locality can be described. Some measurements may be a little high. Details will vary. The section of one part of an exposure may be different from that of another. The details will depend on how the section is classified. Not all investigators will give a clay the same colour designation.

WHITEMUD CLAYS

Eastend Area

Quarrying in Eastend area has been confined mostly to the White clay zone and to the plastic clays occurring therein. The sandy clay of the lowest or sandy clay zone has not been worked. There has been no demand for it and much of it is of very low grade. There is, however, some sandy clay of fair quality in the sandy clay zone south and west of Knollys.

In this area the erosional unconformity between the Ravenscrag and Whitemud formations has an important influence on the location of pits and quarries. For obviously along the unconformity where a large part or all of the workable clay zone is cut out by descent of the Ravenscrag beds, no quarries will be located. Thus there are no quarries and never will be any for the winning of plastic clay on the north side of Frenchman Valley between near the west boundary of Sec. 30, Tp. 6, Range 22, W. 3rd Mer., and the middle of Sec. 29, Tp. 6, Range 22, W. 3rd Mer., and, in places, between the latter location and SE. Sec. 6, Tp. 7, Range 21, W. 3rd Mer. Very little of the White clay zone remains north of SE. Sec. 8, Tp. 7, Range 21, W. 3rd Mer., along the west side of Eastend Coulée and at Anxiety Butte. Only a few feet of the bottom of the sandy clay zone is left. On the south side of the valley, where some good deposits occur, there are also places where the clay zone is missing and where no openings for plastic clays will ever be possible.

On the north side of Frenchman Valley between Ravenscrag Butte and a little east of the west boundary of Sec. 30, Tp. 6, Range 22, W. 3rd Mer., the entire section of the Whitemud formation seems to be preserved. At Ravenscrag Butte, in about the east part of Sec. 26, Tp. 6, Range 23, W. 3rd Mer., the White sandy clay and Brown shale zones were sampled. The results are given in Table 1. Only low-grade clay occurs here in these zones. A little to the east of the above in NW. Sec. 25, Tp. 6, Range 23, W. 3rd Mer. (*See* Table 2), the White clay, Brown shale, and sandy clay zones were sampled. The sandy clay sampled, W50, is of low grade and contains only 13·8 per cent clay by elutriation test. The thin Brown shale zone does not contain any refractory clay. The upper part of the White clay zone, however, does carry good clays of types (1) and (4). The clay zone along this stretch is, therefore, worthy of investigation. In a section in the southwestern part of NE. Sec. 25, Tp. 6, Range 23, W. 3rd Mer. (Table 3), only a part of the clay zone was sampled. The sandy clay zone was sampled near the top. It is low in percentage of clay, W41 contains 20·8 per cent clay. About ¼ mile east of this, in the southern part of NE. Sec. 25, Tp. 6, Range 23, W. 3rd Mer., both the clay and sandy clay zones were sampled (Table 4) and tests show clays of types (2), (4), (6), (7), etc., but the beds are too thin to be of commercial value. Possibly there is better clay in some of the outlying, slumped masses down the valleyside. W36 contains 34·2 per cent clay by elutriation test, W1675 contains 25·4 per cent, and W35 contains 19·8. Farther east and on about the boundary between NW. Sec. 30 and SW. Sec. 30, Tp. 6, Range 22, W. 3rd Mer., the section was again measured (Table 5). There is a bed of type (7) clay here.

About 100 yards east of the above section the contact with the overlying Ravenscrag descends and cuts out the White clay zone so that the greenish sand of the Ravenscrag rests on some grey clay of the Brown shale zone (Table 6). The sandy clay of the sandy clay zone is low in refractoriness and in percentage of clay. W1669 contains only 13·8 per cent clay by elutriated test. This kind of a section extends some distance to the east.

At about the west boundary of SE. Sec. 29, Tp. 6, Range 22, W. 3rd Mer., the contact between the Ravenscrag and Whitemud rises so that the White clay zone is again exposed for some distance. Samples collected from the clay zone are recorded in Table 7 and tests show 8 feet of type (7) clay. The clay zone was also sampled some 800 feet east of the above and in about the northern part of SE. Sec. 29, Tp. 6, Range 22, W. 3rd Mer. (Table 8). There are 8 feet of type (7) clay in this section. Not far east of this the contact with the Ravenscrag descends and cuts out most or all of the clay zone.

At the end of a ridge on about the boundary between NE. and SE. Sec. 28, Tp. 6, Range 22, W. 3rd Mer., a part of the clay zone, which reappears there, was sampled (Table 9). Four feet of type (7) clay occur here.

In the northern part of Sec. 34, Tp. 6, Range 22, W. 3rd Mer., there are a few exposures of the clay zone. It was sampled in the northeast corner of the section (Table 10). Farther east and about on the boundary between NE. and NW. Sec. 35, Tp. 6, Range 22, W. 3rd Mer., the Ravenscrag contact descends and cuts out most of the clay zone.

On the east side of a broad side valley northwest of Eastend and in SE. Sec. 1, Tp. 7, Range 22, W. 3rd Mer., near some coal workings, are some poor exposures of sandy clay and clay.

To the southeast of the above, and along the north side of the main valley, the clay zone is gone, because of descent of the Ravenscrag, the Brown shale zone is thick, and the sandy clay zone is of low grade, as the kaolinization has not proceeded very far, which is usual where the Brown shale zone is thick. A section was studied in a small, narrow, side canyon in the east part of NE. Sec. 35, Tp. 6, Range 22, W. 3rd Mer. (Table 11). W1635, W1636, and W1637 are from the Brown shale zone. W1638, from the sandy clay zone, contains only 12 per cent clay. A little to the east of this and at the fence between NE. Section 35 and NW. Section 36 the quality of the sandy clay is a little better.

Somewhat farther east of this, along the same side of the main valley, the contact with the Ravenscrag rises and all of the White clay zone reappears and is preserved almost as far east as SE. Sec. 6, Tp. 7, Range 22, W. 3rd Mer. It contains some clay of good quality and it is not, therefore, surprising that several quarries have been opened along this part of the valley side, i.e. northwest and north of the town of Eastend. The sandy clay zone here contains mostly sandy clay very low in clay or merely unaltered, grey, feldspathic sand. The Brown shale zone is present and contains clay of only very poor grade. There is a good section of the clay zone in a quarry on the side of a cone-shaped hill in about the middle of NW. Sec. 36, Tp. 6, Range 22, W. 3rd Mer. (Table 12). Nine feet 3 inches of type (3) and 7 feet of type (7) clay occur in this section. The presence of the highest grade clay at the top of the clay zone is to be noted, as it is a common position. The Brown shale and sandy clay zones were studied out in front of an old quarry in the northern part of NW. Sec. 36, Tp. 6, Range 22, W. 3rd Mer. (Table 13). W1646 is from the bottom of the White clay zone, which includes silt beds. The clay that was removed from the quarry was above this and was of good grade. W1647, W1648, W1649, and W1650, are from the Brown shale zone and are of low grade. W1651 from the top of the sandy clay zone contains 25·4 per cent clay. Below this, however, the zone consists merely of grey, unaltered, unkaolinized feldspathic sand. W604 contains only 6 per cent clay by elutriation test and W605 only 3·4 per cent. A part of the White clay zone was sampled in SE. Sec. 6, Tp. 7, Range 21, W. 3rd Mer. (Table 14). The best clay is in the upper part of the section and is of type (1) quality. Clay of type (7) also occurs in the section. Neither, however, is sufficiently thick to be economically important.

To the north and near the east boundary of NE. Sec. 6, Tp. 7, Range 21, W. 3rd Mer., a quarry has been operated on the White clay zone. Yet farther north, in about SE. Sec. 7, Tp. 7, Range 21, W. 3rd Mer., in a small side coulée below a farmhouse, a section was sampled (Table 15). W407 is a sample from the top of the sandy clay zone. It yields a cone of only 14 and contains only 12·5 per cent clay. Above it is a zone of brown and grey shale, some sandy clay, lignite, etc., all of low grade. Above is the clay zone that contains good clay at its top, including about 1 foot 8 inches of type (1) quality; 5 feet 7 inches of type (7) occurs in a lower part of this zone. To the north of this and on the west side of Eastend Coulée the contact with the Ravenscrag descends and cuts out the clay zone and finally removes even most of the sandy clay zone, so that at Anxiety Butte only a few feet of the entire formation is left.

The surface on the east side of Eastend Coulée is too low to carry the Whitemud formation.

There are some good deposits of the Whitemud beds on the south side of Frenchman Valley, south and west of Knollys. The White clay zone contains some good clays in places. The White sandy clay zone, too, contains some fair deposits of sandy clay. The White clay zone and even part of the sandy clay zone are cut out in places and their position taken by basal sands, etc., of the Ravenscrag formation; this takes place particularly to the south up some of the small tributary coulées.

Near the boundary between NE. Sec. 15 and SE. Sec. 22, Tp. 6, Range 23, W. 3rd Mer., the section given in Table 16 was measured. At the bottom W1682 represents the sandy clay zone, is of low grade, and contains only 18 per cent of clay. It is overlain by low-grade brown and grey shale and clay. The most refractory clay is at the top of the clay zone. The samples are not general, but selected. Clay of type (3) quality is indicated and there are 10 feet of type (7).

In the northern part of NW. Sec. 14, Tp. 6, Range 23, W. 3rd Mer., the section of Table 17 was measured. W99 is from the top of the sandy clay zone. It contains 39·4 per cent clay by elutriation test and is a fine, sandy clay. The Brown shale zone is represented only by the 2 feet 3 inches of black, carbonaceous shale. The part of the overlying clay zone that was sampled includes no highly refractory clay. Four feet 3 inches of type (7) clay are included.

About 800 feet east of the above, in a side coulée, the section recorded in Table 18 was measured. The sandy clay zone was not sampled, but appears to carry sandy clay, fairly high in clay. The clay zone is not thick. It includes 4 feet of type (7) clay, C67. About 200 yards to the south, up this side coulée, the Ravenscrag beds descend and cut out all of the clay zone and the upper part of the sandy clay zone. Along the main valley side, in about the northeast part of Sec. 14, Tp. 6, Range 23, W. 3rd Mer., the Ravenscrag sands cut down so deep into the sandy clay zone that only about 10 feet of the formation remains.

Yet farther east the contact rises and near the boundary between Secs. 13 and 14, Tp. 6, Range 23, W. 3rd Mer., the clay zone is present, but the only bed sampled is poor (Table 19). W93 contains 29·6 of clay by elutriation test. East of the above there is a good section in the west part of Section 13 which was not sampled. In about the western part NE. Sec. 13, Tp. 6, Range 23, W. 3rd Mer., the following section was measured:

Green sand at base of Ravenscrag—	Feet	Inches
Light green clay and silty clay	1	5
Bluish grey clay, C64	3	8
Grey silt	1	0
Pale green clay	0	10
Chocolate clay	0	8
Green clay	0	10
Grey, fine, sandy clay	0	11
Fine, grey, sandy clay, W92	2	9
Lignite, lignitic shale	0	5
Fine, brownish, sandy clay	1	0
Lignite and lignitic shale	0	10
Grey, sandy clay, brown above	16	0

At the base is the top of the sandy clay zone followed by lignitic shale. Above is at least a part of the clay zone. Over it is the base of the Ravenscrag. Possibly the top of the clay zone is gone. The sandy clay zone was not sampled. A fine sandy clay at the bottom of the clay zone, W92, contains 29·6 per cent clay. Only one bed in the clay zone was sampled, C64. It gives a P.C.E. of only 14. Southeast of the above, in a deep side canyon, the following section was measured:

Ravenscrag sand—	Feet	Inches
Grey, sandy clay		3
Greenish clay		4
Pale grey, sandy clay		6
Greenish clay, C63	1	0
Lignite		7
Brown, carbonaceous shale		9
Lignite	1	3
Grey, sandy clay, W91	35	0

At the base is a thick zone of sandy clay. A sample, W91, taken from near the top, has 24·2 per cent clay grade by elutriation test. Above is a thin brown shale and lignitic zone. Higher is the lower part of the clay zone. The higher part of the clay zone has been destroyed and the basal sand of the Ravenscrag cuts down into and obliquely across it. A sample from the bottom of the clay zone, C63, yields a P.C.E. of only 11. A little farther east and still in Section 13 the Ravenscrag rests directly on the lignite and all of the clay zone is gone.

In the extreme eastern part of Section 13, however, and on the east slope of a deep side coulée, the contact with the Ravenscrag has risen, so that all of the clay zone is preserved (Table 20). Up and down the coulée, however, i.e. north and south, it is cut off by local descents of the contact with the Ravenscrag. This section includes a part of a thick, sandy clay zone, an extremely thin, coaly, and brown shale zone, and a fairly thick clay zone. No general samples across measured layers were taken, but the selected samples give an idea of the quality, if not the quantity, of clay at various horizons. The sandy clay zone contains some sandy clay of fairly high refractoriness and with a moderate percentage of clay grade. Both samples W1660 and W1661 have a P.C.E. of 26. W1660 contains 29·6 per cent clay grade by elutriation test and W1661, 35·8 per cent. The brown shale, W1662, is of no value. The clay zone contains both clay (type (4) or (5) indicated) and silt. This section shows more interesting material than the average. There are more than 20 feet of clay, silt, and shale, samples of which taken at three levels give a P.C.E. of from 26 to 30. They have not been tested sufficiently to definitely state their most economic application, but they should prove of interest to manufacturers of refractories. This clay zone can be traced across the fence into the westernmost part of Sec. 18, Tp. 6, Range 22, W. 3rd Mer., where a good section is exposed on the nose of a high spur (Table 21). This is an interesting deposit and has possibilities as it shows 5 feet 8 inches of type (4) clay. As is not uncommon, the most refractory clay is at the top of the clay zone. Yet farther east, across a coulée and in SW. Sec. 18, Tp. 6, Range 22, W. 3rd Mer., is a good section recorded in Table 22. At the base is a part of the sandy clay zone that was not sampled. Above the coaly layer is much silty clay and some sandy clay of which three samples yield only cones of 16 to 18. Above is silty and sandy clay of cones 26 to 27. W88 contains 29·8 per cent clay. The most important material, a type (1) clay, is at the top (C58).

In the eastern part of SE. Sec. 18, Tp. 6, Range 22, W. 3rd Mer., the Ravenscrag again descends and cuts out the clay zone, so that only a brown shale and a sandy clay zone remain or even only the latter. At this location, on the west side of a valley, about 40 feet of sandy clay is immediately overlain by greenish grey sand of the Ravenscrag formation. No clay zone is present. A sample, W84, from the middle of the sandy clay, contains 27·8 per cent clay grade. On the opposite and east side of the same valley and east of the boundary between Secs. 17 and 18, Tp. 6, Range 22, W. 3rd Mer., the Ravenscrag rests directly on a bed of brown, fissile, carbonaceous shale. This shale is underlain by sandy, micaceous clay. There is no clay zone here. In a southerly direction up this side valley the Ravenscrag descends even farther into the sandy clay zone, so that only a little remains.

For some distance across Section 17 only a lower part of the formation continues to be preserved and there is no clay zone present. However, in SE. Sec. 17, Tp. 6, Range 22, W. 3rd Mer., on the east side of a deep coulée and south of Knollys, the Ravenscrag contact rises and a full section of the Whitemud formation is present. The section is recorded in Table 23. It includes mostly sandy clay and very little clay. There is no Brown shale zone and the White clay zone is thin. It is chiefly interesting on account of its sandy clay. W77 contains 53·8 per cent clay by elutriation test, W76 contains 29·2 per cent, and W70 contains 43 per cent. There is no uniform decrease downward of clay in the sandy clay at this locality. A little to the east of this is a second and long coulée about on the boundary between Secs. 16 and 17, Tp. 6, Range 22, W. 3rd Mer. On the east side of this coulée, and in SE. Sec. 17, Tp. 6, Range 22, W. 3rd Mer., the section of Table 24 was measured. This deposit is not of much importance unless the sandy clays and silts could be successfully treated by washing. W1658 contains 29·6 per cent clay by elutriation test, W1657 contains 29·4, and W1656 contains 44·8 per cent. A few hundred yards south of this the section recorded in Table 25 was measured. There does not seem to be any well-defined clay zone here, but there is some fairly good sandy clay. The percentage of clay in the sandy clays and silts is as follows:

	Per cent
W79	32·0
W80	37·2
W81	32·2
W82	24·6

There is a 2-foot 8-inch bed of type (7) clay in this section.

On this south side of Frenchman Valley the Whitemud is exposed at intervals as far east as Sec. 25, Tp. 6, Range 22, W. 3rd Mer. It has not been studied in detail here, however.

Whitemud Post Office

Down Frenchman River, near Whitemud post office, the banks on either side of the valley are high enough to carry the Whitemud formation. It is exposed on the east side from about Sec. 9, Tp. 6, Range 20, W. 3rd Mer., to about Sec. 19, Tp. 5, Range 19, W. 3rd Mer., and on the west side from about Sec. 28, Tp. 5, Range 20, W. 3rd Mer., to about Sec. 13, Tp. 5, Range 20, W. 3rd Mer. No detailed study of this area was made. There is much sandy clay and some plastic clay present.

Down the river, the entire formation is removed along the erosional unconformity and the Ravenscrag rests on the Eastend or Bearpaw formations. A small remnant of the basal part of the formation is exposed on the east side of Warholes Valley, but it is too small and the material is of too low a grade to be of any value.

Pinto Upland

On the Pinto upland there are a few detached remnants of the Whitemud formation, survivals of the erosion of pre-Ravenscrag time. They are of small size and consist mostly of low grade, whitish-weathering, sandy clay and silt. There is a thin deposit in about Sec. 21, Tp. 2, Range 9, W. 3rd Mer., and a sample is recorded in Table 26. Another deposit in Sec. 24, Tp. 3, Range 10, W. 3rd Mer., was sampled (Table 27).

The Whitemud seems to be absent from all of the south border of the Wood Mountain upland.

Fir Mountain

Along the north border of the Wood Mountain upland the Whitemud seems to be everywhere absent in the west and the Ravenscrag mostly rests on the Eastend there. It reappears, however, in the vicinity of the village of Fir Mountain and extends in intermittent exposures to Wood Mountain Station.

Southeast of Fir Mountain, in a coulée, in about SW. Sec. 8, Tp. 5, Range 4, W. 3rd Mer., is a good section of the Whitemud, which is recorded in Table 28. This locality is recommended to the attention of manufacturers of refractories and producers of ball clays. In this section are 3 feet 9 inches of type (1) clay, 8 feet 10 inches of type (2), and 3 feet 6 inches of either type (1) or (2). The sandy clay is of good refractoriness and fair plasticity. W940 contains 45·6 per cent clay by elutriation test and W938 contains 43·4 per cent.

East of Fir Mountain, north of the highway, south of the railway, and in SW. Sec. 15, Tp. 5, Range 4, W. 3rd Mer., a section was sampled and is recorded in Table 29. There are 19 feet of type (2) clays. W925 contains 53·4 per cent clay, W926 contains 56·4 per cent, and W927 contains 33 per cent. One of the sandy clays (W926) is not typically a type (2) clay, but because its plasticity is considerably better than most sandy clays it is so classified.

Wood Mountain Creek

Exposures of the Whitemud formation are found on the valley sides from about Sec. 16 to about Sec. 34, Tp. 5, Range 3, W. 3rd Mer.

On the east side of the valley, on a cone-shaped butte, between NE. Sec. 27 and NW. Sec. 26, Tp. 5, Range 3, W. 3rd Mer., is a good section of the sandy clay zone (Table 30), with considerable silt in the upper part. The sandy clay is fairly highly refractory and contains a fairly high percentage of clay, but not as high as at some other localities. The percentage of clay grade in the samples is as follows:

	Per cent
W954	41·6
W951	43·6
W955	35·2
W957	35·2
W958	34·6

The upper part of the formation, including the White clay zone, is not well exposed in this locality, but has been sampled about 200 yards to the south of the butte. The results are recorded in Table 31. Underlying a 1-foot 6-inch bed of untested silt occurs 9 feet 7 inches of type (2) clay having a P.C.E. value of cone 30. Separating this clay from another 2-foot 1-inch bed of similar material is a 1-foot 1-inch bed of iron concretions and 8 inches of a grey, friable, untested shale.

It is possible that some Whitemud underlies the upland to the east of this locality, and is concealed there by boulder clay, etc. Also on the east side of the valley, in a long exposure on about the boundary line between SE. Sec. 34 and NE. Sec. 27, Tp. 5, Range 3, W. 3rd Mer., the section of Table 32 was measured. This section was not thoroughly tested, but it may be of interest to manufacturers of refractories and possibly of ball clays. Clay of type (1) or (2), having a P.C.E. value of cone 30, is indicated. The beds are rather too thin, however, to be of economic importance. The sandy clay is refractory and contains 57·6 per cent clay. The east side of this valley should be further investigated as good material might be found.

To the south and on the west side of the valley some deposits were sampled, but are not so promising as the above. In about the southern part of NW. Sec. 15, Tp. 5, Range 3, W. 3rd Mer., the section recorded in Table 33 was measured. The most promising clay was tested, with poor results. A little to the west, and on the same low cliff, the section of Table 34 was sampled. It includes a sandy clay zone below, a Brown shale or clay zone in the middle, and a grey clay zone above. The sandy clay, W1704, gives only a cone of 23 and contains 31 per cent clay. The clays and shales of the Brown shale zone are poor. Some grey, silty clay gives a cone as high as 29. A little farther west (*See* Table 35), below a farm-house, the Brown shale zone is gone, the sandy clay zone is thicker, of higher quality and greater percentage of clay, and the clay zone, though thin, is of high quality. Percentages of clay in the sandy clays are as follows:

	Per cent
W1716	34·4
W1715	32·4

W1718 is of type (2), but the bed is thin. Yet farther west, along the same cliff, and west of the farmhouse, is the section recorded in Table 36. The sandy clay, W1719, contains 30·4 per cent clay. Yet farther along this cliff the entire section of the formation deteriorates and becomes quite valueless.

Gollier Creek

There are good exposures of the Whitemud formation in a part of Gollier Valley. In the south the Whitemud dips below the Ravenscrag formation. In the north, toward Twelvemile Lake, it is cut out along the erosional unconformity and the Ravenscrag rests directly on the Eastend formation.

A deposit on the east side of the valley, north of the highway, in SE. Sec. 17, Tp. 5, Range 2, W. 3rd Mer., was measured and the results are recorded in Table 37. The upper part of the sandy clay zone is represented by W901, which contains 33·6 per cent clay by elutriation test. The remainder of the section belongs to the clay zone, except W902 which may represent the base of the Ravenscrag. The clay zone includes 6 feet 4 inches of type (2) and 3 feet 7 inches of type (4).

On the west side of the valley, in SW. Sec. 17, Tp. 5, Range 2, W. 3rd Mer., is a thick exposure of the sandy clay zone.

	Feet	Inches
Sandy clay	17	
W907 from near base		
Brown, sandy clay	0	5
Sandy clay	27	0
W908 from 10 feet below top		
W909 from near base		

No ceramic tests were made, but the percentages of clay in the samples of sandy clay are as follows:

	Per cent
W907	48·2
W908	36·0
W909	32·6

Above this sandy clay and under the boulder clay, at the top of the cliff, is a little pale green and purplish clay. This might be found to thicken if followed back farther into the hill. The overburden is light and the deposit might be further investigated.

These occurrences on Gollier Creek are worth further study. They are, however, situated some distance from the railway.

Twelvemile Lake

The Whitemud is entirely absent along the erosional unconformity and the Ravenscrag rests directly on the Eastend in the western part of Twelvemile Lake. It is, however, preserved over much of the eastern part of the lake. Even there it was removed in places along the erosional unconformity and in a few places is faulted below lake-level. Where present it is mostly poorly developed and thin. The samples taken are mostly of low grade, but, of course, sufficient have not been taken to state positively that no good clays are present. Along the north shore there are intermittent exposures between the east part of Sec. 22, Tp. 6, Range 2, W. 3rd Mer., and Sec. 9, Tp. 6, Range 1, W. 3rd Mer., inclusive. On the south shore there are intermittent exposures between the east part of Sec. 11, Tp. 6, Range 2, W. 3rd Mer., and the west part of the SW. Sec. 9, Tp. 6, Range 1, W. 3rd Mer., inclusive. Only a few sections will be given.

In the middle part of SW. Sec. 23, Tp. 6, Range 2, W. 3rd Mer., on the east side of a bay on the north side of the lake, is the section recorded in Table 38. The basal 25 feet belong to a very shaly phase of the Eastend. The overlying three beds are sandy clays. They have not been tested, but W714 contains 34 per cent clay and W715 contains 35·6 per cent. W716 is a feldspathic sand.

On the next point to the east of this the Whitemud formation is absent and the Ravenscrag rests on the Eastend.

In about NW. Sec. 12, Tp. 6, Range 2, W. 3rd Mer., and on the east side of a fault, there is a low cliff of whitish and greenish sandy clay overlain by grey silt, clay, etc. This dips to the east below lake-level near the east line of NW. Section 12. Farther east and on the north side of the lake some clay is present in the northern part of the NE. Section 12. A cone-shaped butte in the northern part of Sec. 7, Tp. 6, Range 1, W. 3rd Mer., has the following section:

	Feet
Grey, sandy clay (W877)	4
Greenish, sandy clay	8
Thin-bedded, greenish, fine sand, silt, grey clay, etc.	

The greenish, sandy, and grey, sandy, clay apparently belong to the Whitemud formation, the top part of which is eroded off here. The thin-bedded layers below are of the Eastend formation. The sample W877 gives a P.C.E. of 18, is fairly plastic, and has fairly good working properties. It is, however, of no value, being full of a soluble salt that melts on the surface. It is also very sandy.

A little east of the above and in the western part of NE. Sec. 7, Tp. 6, Range 1, W. 3rd Mer., and near the shore is about 6½ feet of greenish, sandy clay (W874) with films of plant debris and vertical roots. The P.C.E. is 12. It is fairly plastic and the drying behaviour is satisfactory.

For some distance to the east the Whitemud is cut out, so that the Ravenscrag directly overlies the Eastend.

A little north of the centre of Section 8 and west of a broad valley there is about 9 feet of greenish, sandy clay (W870). It has a P.C.E. of 17. It has some plasticity, but cracks very badly.

On the same and north side of the lake and on the east side of the same broad valley is a long spur at the southern end of which Whitemud sandy clay outcrops. A little to the east the entire section passes over into dark silt, shale, clay, etc., of no value. In the middle of NW. Sec. 9, Tp. 6, Range 1, W. 3rd Mer., however, the Whitemud sandy clay reappears, a section of which is given in Table 39. W857 contains 42·4 per cent sand grade and 37·6 per cent clay grade. Type (9) is indicated.

On the south shore of Twelvemile Lake no trace of Whitemud formation was found west of NE. Sec. 11, Tp. 6, Range 2, W. 3rd Mer., for there the Ravenscrag rests directly on the Eastend. In the northern part of NW. Sec. 1, Tp. 6, Range 2, W. 3rd Mer., about 12 feet of white to grey, sandy clay was sampled (W756). It contains only 13 per cent clay. There are a number of Whitemud exposures in a valley in NE. and SE. Sec. 1, Tp. 6, Range 2, W. 3rd Mer. At one place 10 feet and in another 4 feet of sandy clay were measured. In the western part of SE. Sec. 7, Tp. 6, Range 1, W. 3rd Mer., on the west side of a spur, the Whitemud section is as in Table 40. Sixteen feet 9 inches of this material is of type (6) quality. W991, of sandy clay, contains 41 per cent clay. In NE. Sec. 5, Tp. 6, Range 1, W. 3rd Mer., the Whitemud section includes:

4 feet 6 inches whitish clay, minute ferruginous grains
1 foot 6 inches sandy clay, W803
W803 contains 45·8 per cent clay

Thus the Twelvemile Lake deposits are not very promising.

In about SW. Sec. 9, Tp. 6, Range 1, W. 3rd Mer., the Whitemud formation goes down below lake-level and does not reappear to the east anywhere in Twelvemile Lake valley.

Willows-Readlyn Area

Some good deposits have been found in this area. Several quarries have been operated. The Whitemud formation is here about 35 feet thick. It shows considerable variation. Typically there is a sandy clay zone below and a clay zone above. The best clays are in the top of the clay zone.

An unworked deposit occurs on the east side of the valley at the south end of Lake of the Rivers and in SW. Sec. 7, Tp. 8, Range 28, W. 2nd Mer. A section is recorded in Table 41. Just where this section was made there is very little sandy clay at the base. Its place is mostly taken by low-grade clay and silty clay. There is good clay in the clay zone, however, which includes 7 feet of type (1), 8 feet of type (2), and 6 feet 8 inches of type (4), quality. The measurements may be a little high. The overburden is not thick at this locality.

Table 42 records the top part of the Whitemud section in a small quarry, south of the above locality, just north of the highway and in NE. Sec. 1, Tp. 8, Range 29, W. 2nd Mer. There are some ferruginous concretions in this clay. It is being worked as an upper bench. Clays of types (1) and (2) are found here. This clay is underlain by brown to black, carbonaceous clay which was not tested. Below it is a fine, sandy clay with fossilized, long, tap-like roots. A small amount of it has been removed on a lower bench.

Immediately south of the above quarry, and south of the highway, is the quarry from which a large tonnage has been shipped to Medicine Hat. Practically the whole Whitemud section was utilized in this quarry and all was worked as one bench. The overburden is increasing to the east, under the upland. No study was made of this quarry.

In a coulée northwest of Willows the Whitemud is exposed in a number of places and shows much variation. An exposure on the north side of this coulée, in SW. Sec. 3, Tp. 8, Range 29, W. 2nd Mer., shows a good section of sandy clay or kaolinized feldspathic sand, which is well developed, and is recorded in Table 43. It is of interest to note not only the considerable thickness of the sandy clay here, but the decrease in degree of refractoriness downward and that this decrease is more or less, not exactly, correlated with decrease downward in percentage of clay in the sandy clay. The kaolinization is dying out downward. The proportion of clay in the sandy clays by elutriation test is as follows:

	Per cent
W1207	56·2
W1208	41·8
W1209	33·6
W1210	40·4
W1211	32·0
W1212	29·0
W1213	25·2

These sandy clays vary in refractoriness from cone 10 to cone 29, are only slightly plastic, and are only important when and if the practice of washing the sandy clays is adopted. Although no good plastic clays are present in this section, it should be noted that the top of the clay zone is not exposed here. Excavation back into the cliff and under the upland might possibly open up better clay.

A deposit of Whitemud sandy clay is exposed near the railway trestle, just west of Willows. It was not sampled.

A good natural exposure of the Whitemud occurs in a high cliff in SW. Sec. 30, Tp. 7, Range 28, W. 2nd Mer. A section is recorded in Table 44. There is sandy clay below and plastic clay above. This is a good locality for the more important clays. Tests show the deposit to contain 8+ feet of type (1), 8 feet of type (2), 2 feet 8 inches of type (3), 1 foot 1 inch of type (4), and 2 feet 6 inches of type (6), clay. The sandy clay samples contain the following percentages of clay by elutriation test:

	Per cent
W1277	43·4
W1275	43·0
W1273	40·6
W1271	45·8

The measurements may be a little high.

A rather thin section, possibly not including the top of the clay zone, was measured on the north side of a small coulée west of the highway on SE. Sec. 24, Tp. 7, Range 29, W. 2nd Mer. (Table 45). There is sandy and silty clay below and clay above. Clays of types (2), (3), (4), and (6) are included. They are somewhat ferruginous. All crack to some extent. W1354 contains 56·6 per cent clay.

Clay has been quarried in about the northern part of Sec. 28, Tp. 7, Range 28, W. 2nd Mer., and shipped to Estevan. No study was made of this deposit.

Whitemud clays are also exposed in the vicinity of Readlyn, but were not sampled.

Willowbunch Lake Area

On the east side of the valley, between Readlyn and what is here called the Verwood trestle, there are not many exposures of the Whitemud. Over much of this stretch it seems to lie low on the valley side and west of the railway track. On the west side of the valley, in places at least, it may be faulted down below valley level, or is so low that it is covered with alluvium, etc. East of the Verwood trestle and north of highway 13, in SE. Sec. 6, Tp. 7, Range 27, W. 2nd Mer., and at the end of a high spur the section measured in Table 46 is exposed. Here sandy clay is overlain by silty clay and at the top is clay. W1214, of sandy clay, contains 51 per cent clay. The clay zone includes 8 feet of type (2) clay. This deposit is overlain by about 10 feet of grey to grey greenish silt, shale, etc., and above it is a thin coal seam probably identical with, or about at the horizon of, the one immediately above the Whitemud in the Willows area. Those who favour the alteration of clays by descending swamp waters might see in the position of the coal bed at Willows a confirmation of their view, but would find nothing at this locality to support it.

South of the above and just north of highway 13, east of the Verwood trestle, is a small pit from which a test shipment has been made. Three feet of clay (type (4)) in the upper part of the section gave the results recorded in Table 47. It may not be at the very top of the formation.

Along the east side of the valley between the Verwood trestle and the lake no deposit of the Whitemud formation occurs. It is possible that the grey sands that outcrop there are of Sand E and underlie the Whitemud beds. On the west side of the valley Sand E, and in places the Eastend outcrop on the valley side. What appeared to be sandy clay at the base of the Whitemud was found up a side coulée to the west and there the Whitemud should be sought.

On the west side, where the lake shore turns eastward a north-south coulée enters the main valley. It is west of the highway in Sec. 12, Tp. 6, Range 28, W. 2nd Mer. On the west side of this coulée only a coal seam and beds low in the Ravenscrag formation outcrop. On the east side, however, the Whitemud is exposed. There is, of course, a fault down the centre of the valley. Some clay has been removed in a tunnel and a small experimental plant has been operated nearby. There is sandy clay below and plastic clay above. This section was not sampled in the course of this investigation, but good clay is said to be present.

Just east of the above, east of the highway, in another coulée, in Sec. 7, Tp. 6, Range 27, W. 2nd Mer., and on the south side of Willowbunch Lake, is a good exposure of the Whitemud formation. A section made on the east side of this coulée, just south of a small fault, is recorded in Table 48. It includes 3 feet of type (1), 8 feet of type (3), and 7 feet 4 inches of type (4), clay. The bed of W1303 in which the small ferruginous concretions are concentrated would have to be discarded. The sandy clays contain the following percentages of clay by elutriation test.

	Per cent
W1299	54·4
W1298	45·2
W1297	38·8
W1296	37·6

North of the fault the clays were not tested.

To the east in another coulée, south of the lake, there are exposures of the Whitemud clay. Also, along the south shore of the lake there are discontinuous deposits as far east as about SE. Sec. 9, Tp. 6, Range 27, W. 2nd Mer. Beyond this the Whitemud goes below lake-level and does not reappear on the lake shores to the east. In SE. Sec. 9, Tp. 6, Range 27, W. 2nd Mer., is the section recorded in Table 49. It includes a few feet of the top of the formation. Only cone tests were made. Highly refractory clays are included. The overburden is from 30 to 40 feet and increases back into the hill.

Big Muddy Valley

It has been stated that, owing to the regional east dip, the Whitemud formation descends and disappears below lake and valley level near the east end of Twelvemile Lake in Twelvemile Lake Valley and near the west end of Willowbunch Lake in Lake of the Rivers Valley. It rises again and reappears, on a low structural arch, in Big Muddy Valley, between Tp. 3, Range 25, W. 2nd Mer., and Big Muddy Lake. The total thickness of the formation exposed here is about 35 feet, but the base has not been observed. It shows considerable variation, but there is mostly sandy clay at the base, clay above, and the best clay mostly at the top of the clay zone. At most, if not all, exposures the overburden is too great to permit open pit work.

On the south side of Big Muddy Valley, west of the highway (34) south from Bengough, and near the centre of Sec. 27, Tp. 3, Range 24, W. 2nd Mer., is the section of the Whitemud formation recorded in Table 50. At the top is 9 feet of type (2) clay having a P.C.E. of +30. Below is some 9 feet of very fine, sandy, and somewhat silty clay and clays (types (4) and (6)) which burn buff or cream, are less refractory than the top 9 feet and less likely to crack. At the base is some 16 feet of sandy clay. The percentage of clay in the sandy clay is as follows:

	Per cent
W1168	48·8
W1169	47·0
W1170	43·6
W1171	48·0

About 150 feet to the east along the cliff the bottom part of the sandy clay zone changes a little. The section there is recorded in Table 51. The percentage of clay in the sandy clay is as follows:

	Per cent
W1175	51·6
W1174	42·2
W1172	49·6

The overburden of Ravenscrag sand, hard sandstone ledges, and clay is about 50 feet in the front part of the cliff and more than 100 feet to the rear, on the higher cliff.

Farther west along the south side of the valley the Whitemud is exposed in places, near or at the bottom of the high cliffs. In about SE. Sec. 20, Tp. 3, Range 24, W. 2nd Mer., is an exposure of the very top of the clay zone of the Whitemud. It is recorded in Table 52. The clay is refractory, but none other than P.C.E. tests were made. W1504 would probably need washing. Although these clays have P.C.E. values of 31 + and are of type (1) or (2), the beds are very thin.

Much farther west along the south side of the valley, at the end of a high spur, in NE. Sec. 24, Tp. 3, Range 25, W. 2nd Mer., the section recorded in Table 53 was measured. It includes the top part of the clay zone overlain by Ravenscrag carbonaceous shale and lignite. This material is highly refractory and of type (1).

Yet farther west along the same side of the valley, in about the middle of Sec. 25, Tp. 3, Range 25, W. 2nd Mer., a thick section of the formation is exposed in a high cliff. The measurements are recorded in Table 54. It shows great variation in refractoriness of individual beds. It supports the theory of weathering and alteration, bed by bed, i.e. penecontemporaneously with deposition. The most refractory clay is at the top of the clay zone, however. The sandy clay zone instead of being massive is separated by many beds of low-grade clay and silty clay. Not much high-grade, sandy clay, therefore, occurs in the section. The total thickness is below 35 feet. The clays of this section include: 9 feet of type (2), 2 feet of type (3), 8 inches of type (4), 2 feet 10 inches of type (5), and 1 foot 9 inches of type (6), quality.

On the north side of the valley, in about SW. Sec. 2, Tp. 4, Range 25, W. 2nd Mer., a section was sampled and is recorded in Table 55. The clays in this section are not very refractory. They burn to cream and buff colours and include types (4) and (5).

Along the north side of the valley there are few exposures for some distance. From Range 24 eastward, however, there are many exposures that should be examined. They are mostly in high cliffs and could hardly be quarried.

From near the crossing of highway 34 to near the west end of Big Muddy Lake there are few exposures of the Whitemud. It appears to go below valley level there on both sides. At the west end of Big Muddy Lake, on the south side are several exposures, mostly of the top beds of the formation. The top beds show in NE. Sec. 15, Tp. 3, Range 23, W. 2nd Mer. A sample is recorded in Table 57. A 1-foot bed is of type (2) clay. On a small butte in Sec. 14, Tp. 3, Range 23, W. 2nd Mer., sandy clay, cone 29, is overlain by pale greenish grey clay, cone 28. Just southeast of this small butte, at the end of a short spur, is a 1-foot bed of type (1) clay (Table 56). A little sandy clay also shows on the north side of the lake, near its western end.

Other Localities

The Whitemud, of course, occurs at other localities, but they were not studied. It has been reported near Brooking. The beds at Halbrite may represent an eastern extension of the Whitemud. Extended quarrying has been done at Claybank and important refractory products manufactured. Other deposits include those in the Cactus Hills south of Moose Jaw, west of Moose Jaw, and near Beechy.

WILLOWBUNCH CLAYS

The more important Willowbunch clays are, for ceramic purposes, practically all of types (4), (5), and (6). They are buff burning rather than white burning, although some are white burning. The Whitemud clays seem to be more of the types (1), (2), and (3).

Willowbunch Area

In Willowbunch area the Willowbunch member underlies the high upland southwest, south, and southeast of the town of Willowbunch and is exposed high in the coulées heading into the upland from the main valley. The upland on the north side of the valley is too low to carry it. It lies just below the thick Willowbunch coal seam. Exposures extend from Sec. 21, Tp. 5, Range 28, W. 2nd Mer., to Sec. 4, Tp. 5, Range 27, W. 2nd Mer.

Most of the section given in Table 58 was measured, south of a fence, in NW. Sec. 15, Tp. 5, Range 28, W. 2nd Mer. The two lowest beds were measured and sampled a couple of hundred feet to the northwest, across the fence. At the base is sandy clay. W1063 contains 24 per cent of clay by elutriation test. This is one of the few occurrences of sandy clay in the Willowbunch member. The grey, very fine sand and silt over it was not tested. Above there is first low-grade and then higher grade clay of types (1) and (4) (indicated). At the top are low-grade clays.

On the west side of a coulée, below a coal tunnel, southwest of Willowbunch and in the northern part of SE. Sec. 14, Tp. 5, Range 28, W. 2nd Mer., the section given in Table 59 was sampled. Samples tested show poor clays overlying a 3-foot 4-inch bed of type (4) clay. Only the very top of the zone is included in this table.

A section taken about 100 yards east of the above is recorded in Table 62 and includes most of the Willowbunch member. This section shows 3 feet of type (2) clay, 2 feet 9 inches of type (5), and 2 feet 10 inches of type (7).

An exposure of clay north of the bend in the highway in SW. Sec. 7, Tp. 5, Range 27, W. 2nd Mer., was measured (Table 60). It consists of 6 feet 6 inches of type (1) clay.

West of Bonneau Lake, on the west side of a long coulée, in NE. Sec. 4, Tp. 5, Range 27, W. 2nd Mer., is the section of the Willowbunch member recorded in Table 61. W1320 is a sandy clay and has 26·6 per cent clay. W1322 is finer and has 38·8 per cent clay. This section shows that 3 feet 8 inches of type (1) clay are underlain by 5 feet 3 inches of type (9) sandy clay. The remaining clays from this section are of little economic value.

At a lower horizon in the Ravenscrag, about 120 feet below the Willowbunch member, and down the same coulée on its west side, in about SW. Sec. 3, Tp. 5, Range 27, W. 2nd Mer., is a zone of clay recorded in Table 63. It attracted attention because of its pale weathering colours. Samples, however, do not disclose the presence of any refractory clay.

Harptree

For some distance east of the above locality the valley sides are not high enough to carry the Willowbunch member. South of Harptree, however, on the south side of the valley, the high cliffs of the tributary coulées carry the Willowbunch member. Two clay zones are worthy of consideration. The higher one contains some fair clay only at one locality and is difficult to identify elsewhere in the area. The lower one, 40 feet below it, is of wider extent, although variable, and in places is also difficult to recognize. It was traced from about SW. Sec. 8, Tp. 4, Range 26, W. 2nd Mer., to about NE. Sec. 33, Tp. 3, Range 26, W. 2nd Mer. The cliffs on the north side of the main valley south of Harptree are not high enough to carry the Willowbunch.

The lower zone was sampled in NW. Sec. 5, Tp. 4, Range 26, W. 2nd Mer. A section is given in Table 64. There is no sandy clay zone. Silty clay is present, however. The section is a very interesting one containing as it does 2 feet 10 inches of type (3) clay (P.C.E. 27) and 10 feet 2 inches of type (4) (P.C.E. 19 to 28), and exhibiting good working, drying, and burning properties.

The same zone was sampled in NE. Sec. 5, Tp. 4, Range 26, W. 2nd Mer., and the section is recorded in Table 65. The tests were not comprehensive on these samples, but indications are that clay of types (4) and (9) are present in beds of workable size.

A good section of the lower zone is exposed just west of the road to Coronach, in about NE. Sec. 33, Tp. 3, Range 26, W. 2nd Mer., on the east side of a coulée, and a little below the level of the upland. It is recorded in Table 66. The tests of materials from the section showed the presence of clays of types (1), (2), and (4). The clays of types (1) and (2) do not crack in drying as is usual with the Whitemud clays.

The higher zone was sampled in NE. Sec. 5, Tp. 4, Range 26, W. 2nd Mer. A section is given in Table 67. Although clays of type (4) and type (7) are represented in this section, the beds sampled are too thin to be worked.

Buffalo Gap

Refractory and semi-refractory clays also occur in the vicinity of Buffalo Gap. They appear to be at the horizon of the Willowbunch member. Outcrops are few, however, and the exact stratigraphic position is difficult to determine. On the east side of the road through the gap, and in about the southern part of Sec. 11, Tp. 3, Range 25, W. 2nd Mer., under burnt shale is some grey shale. A sample of it is recorded in Table 68.

About 3½ miles northwest of Buffalo Gap, near the end of a northward-extending spur, and in about Sec. 17, Tp. 3, Range 25, W. 2nd Mer., are fine sandstones, shales, etc., weathering pale yellowish, etc. High in the exposed section are the clays recorded in Table 69. Although refractory clay of probably type (1) or (2) is present the bed is not of sufficient thickness to warrant development.

Big Muddy Valley

On the south side of Big Muddy Valley, east of the Bengough (34) highway, and in Sec. 13, Tp. 3, Range 24, W. 2nd Mer., at a high elevation, the section recorded in Table 70 was measured. Tests show it to contain 3 feet of type (5) clay, 4 feet of type (6), and 4 feet 7 inches of sandy clay of type (9).

Big Muddy Lake

The Willowbunch member is well exposed on the high escarpment south of Big Muddy Lake and on both sides of the valley between the lake and the International Boundary, except on the west side in the vicinity of Big Muddy post office.

In about NW. Sec. 7, Tp. 2, Range 22, W. 2nd Mer., the section recorded in Table 71 was measured. Under a 3-foot overburden of poor quality clay are 14 feet of clay of type (5).

A section, measured on the west side of a coulée, and directly west of the Keogh ranch house, is recorded in Table 72. Tests show the presence of clays of types (5) and (7).

On the east side of the Big Muddy Valley, south of the lake and in NE. Sec. 1, Tp. 2, Range 22, W. 2nd Mer., is the section recorded in Table 73. There are indications of the presence of type (1) or (2) clay, underlying clay of poor quality.

Legere Coulée

At several localities in Legere Coulée, east of Old Wood Mountain, exposures of the Willowbunch clays occur on the valley sides. The section recorded in Table 74 is in about NW. Sec. 18, Tp. 4, Range 2, W. 3rd Mer., on the west slope of a high hill. Tests indicate the presence of types (4) and (6), but the beds are too thin to be of economic importance.

The section recorded in Table 75 is in NE. Sec. 13, Tp. 4, Range 3, W. 3rd Mer. Clay types (1) and (4) occur in the deposit in beds of workable size.

The section recorded in Table 76 is on a hill, north of the east-west road through Legere Coulée and in Sec. 23, Tp. 4, Range 3, W. 3rd Mer. There is no clay of economic importance in this outcrop.

Canopus to Kildeer

Between Canopus and Kildeer, on the south side of the railway, at high elevations, are exposures of what is probably the Willowbunch member. Just south of the siding, near the Lugenville farm, west of a north-south road and in approximately Sec. 36, Tp. 2, Range 3, W. 3rd Mer., is the section recorded in Table 77. Clay of type (7) is present, but the beds are too thin to be of economic importance. On the east side of the same road a few feet of clay was measured. The results are given in Table 78. Clay of type (4) occurs, but the thickness is not recorded.

Northeast of Kildeer, in SW. Sec. 13, Tp. 2, Range 3, W. 3rd Mer., on the south side of a high butte, is a section, recorded in Table 79. Type (4) clay is indicated, but the thickness of the bed is too small to be of economic importance.

Some clay, at a much lower horizon, in the Ravenscrag, was sampled at the turn in the road, in the east part of Sec. 34, Tp. 2, Range 3, W. 3rd Mer. This is recorded in Table 80. The one clay tested from this locality is of little economic importance.

Rockglen

At high elevations in the vicinity of Rockglen, is a zone of clays resembling those of the Willowbunch member. A second zone below it is also worth noting. These deposits are on the Coronach branch of the Canadian Pacific Railway.

North of Rockglen, in about the centre of Sec. 11, Tp. 3, Range 30, W. 2nd Mer., at the top of a cone-shaped hill, is a section of what is probably the Willowbunch member. It is recorded in Table 81. The tests show the presence of type (6) clay in a bed of workable size.

Near, but west of, the above, and in about Sec. 11, Tp. 3, Range 30, W. 2nd Mer., is the section recorded in Table 82. Although type (5) clay is noted here, the thinness of the bed makes it of little economic value. Clay also occurs at a lower horizon, about 80 to 100 feet below the above zone, which is apparently the Willowbunch. It is in SW. Sec. 11, Tp. 3, Range 30, W. 2nd Mer., and is recorded in Table 83. Although clay of type (6) occurs here, its thickness (1 foot) makes it of little economic importance.

What is also probably at a lower horizon is a small zone to the southwest of Rockglen, in about SW. Sec. 33, Tp. 2, Range 30, W. 2nd Mer. A section is given in Table 84. Types (1) and (4) clays occur here in very thin beds. The beds are too thin to be of economic value.

The higher and probable Willowbunch zone was sampled at the east end of a high ridge in the southern part of Sec. 26, Tp. 2, Range 30, W. 2nd Mer. A section is given in Table 85. The showing is poor.

A good section of the Ravenscrag is exposed on the east side of Rockglen Valley, in SW. Sec. 29, Tp. 2, Range 29, W. 2nd Mer. At the top is what is possibly the Willowbunch zone (Table 86). Clays of types (4) and (6) are found here but in too thin beds to work.

About 10 feet below the above is the section recorded in Table 87. Clays tested from the section are poor.

About 25 feet below the above is a section recorded in Table 88. Clays tested from the section are of little value.

About 100 feet below this is the bed recorded in Table 89. Clays tested from this section are of little value.

Near the International Boundary, in Sec. 2, Tp. 1, Range 24, W. 2nd Mer., about 10 to 15 feet of whitish silt is exposed that may be of the Willowbunch member. A sample taken from near the middle is recorded in Table 90. It is of little value.

APPENDIX I: CERAMIC TESTS

Supervised by J. G. Phillips

TABLE 1

Locality: Ravenscrag Butte, in about the east part of Sec. 26, Tp. 6, Range 23, W. 3rd Mer.

Thickness		Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
Ft.	Ins.													
...	...	...	...	Clay and sandy clay	...	...	...	...	...	...	...	...	...	...
...	...	...	...	Black, slightly coaly, carbonaceous shale	...	...	...	...	...	...	...	...	...	...
...	...	W1634	Not classified	Brown clay.......	25	Plastic, very good	17	...	...	...	...	...	...	...
...	...	...	...	Clay............	...	...	...	...	...	...	...	...	...	...
...	...	W1633	Not classified	Very fine, sandy clay. Sample 3 feet below brown clay	21	Slightly plastic, fairly good	19+	...	...	...	...	...	...	...
...	...	W1632	Not classified	Very fine, sandy clay, just over W1631	21	Very short, poor..	16	...	...	...	...	...	...	...
0	6	W1631	Not classified	Dark grey clay about 5 feet above W1629	36	Very plastic, good	12	...	...	...	...	...	...	...
...	...	W1630	Not classified	Finer, grey, sandy clay above W1629	24	Very short, poor..	16	...	...	...	...	...	...	...
...	...	W1629	Not classified	Light grey, very coarse sand 15 feet below coaly layer	19	Very short, poor..	15	...	...	...	...	...	...	...

Table 2

Locality: North side Frenchman River, in southern part of NW. Sec. 25, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	6	C23	1	Grey clay........	27·5	Good............	30	....	8·5	2 4 6	5·5 6 6	9·6 8·3 7·4	Fair, white Fair, white Fair, white	Very hard Very hard Very hard
1	5	C24	4	Light green clay	23	Good............	26	....	8	2 4 6	4·5 4·5 4·5	9·6 7·5 6·2	Fair, white Grey....... Cream......	Very hard Very hard Very hard
1	2			Chocolate clay										
2	0	W47	Not classified	Pale green, fine silt	22·4	Tends to be short, good	23+	....	....	....	....	....	....	....
3	5	C25	7	Pale grey, pale green clay	27	Good............	18	....	8·5	2 4 6	5 5·5 7·5	6·7 4·7 1·1	Light grey Cream-grey Cream-grey	Very hard Very hard Very hard
1	9	....	....	Fine silt and clay.	....	....	....	....	....	....	....	....	....	....
1	0	C26	7	Clay............	27	Good............	17	....	7	4 6	8 8	Neg...... Neg......	Grey....... Grey.......	Steel hard Steel hard
5	0	W48	Not classified	White silt, a little clay	21	Tends to be short, good	20+	....	....	....	....	....	....	....
1	7	....	....	Pale buff silt.....	....	....	....	....	....	....	....	....	....	....
1	2	C27	7	Chocolate clay....	33	Good............	12	....	10·5	2 4 6	5·5 3·5 3	Neg...... Neg...... Neg......	Drab....... Poor brown Poor brown	Steel hard Steel hard Steel hard
1	10	C28	7	Greenish clay.....	25	Good............	11+	....	8·5	4 6	4 5	3·5 Neg......	Poor brown Poor brown	Steel hard Steel hard
2	1	W49	10	Black to brown, carbonaceous, silty clay	25·3	Tends to be short, good	20	....	....	....	....	....	....	....
0	10	....	....	Coal............	....	....	....	....	....	....	....	....	....	....
3	0	....	....	Brown sand......	....	....	....	....	....	....	....	....	....	....
10	0	W50	10	Grey, medium sandy olay	24·3	Very short, poor..	16	....	....	....	....	....	....	....

Table 3

Locality: SW. part of NE. Sec. 25, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	8	W42	...	Greenish yellow weathering silt	...	...	...	...	...	...	...	...	...	...
2	0	C21	Not classified	Dark shale, plant debris Top Whitemud?	37·5	Good, plastic	8	...	14	2	1	2·5	Poor	Very hard
1	0	C18		Brownish and greenish clay	26	Good, plastic	19+	...	9	2	2·5	9·2	Cream	Very hard
			7	...	...	...	...	...	...	4 6	2·5 2·5	6·9 3·6	Cream Cream	Very hard Very hard
1	9	W39	...	Fine, sandy clay	...	...	...	...	...	...	...	...	...	...
0	9	...	...	Pale greenish clay	...	...	...	...	...	...	...	...	...	...
0	6	...	...	Fine sand	...	...	...	...	...	...	...	...	...	...
0	9	...	...	Bluish grey clay	...	...	...	...	...	...	...	...	...	...
0	5	...	...	Fine sand	...	...	...	...	...	...	...	...	...	...
0	10	...	...	Silty clay	...	...	...	...	...	...	...	...	...	...
0	4	...	...	Pale greenish clay	...	...	...	...	...	...	...	...	...	...
0	7	...	...	Brownish clay	...	...	...	...	...	...	...	...	...	...
0	4	...	...	Pale greenish, fine sand	...	...	...	...	...	...	...	...	...	...
1	0	...	...	Silty clay	...	...	...	...	...	...	...	...	...	...
0	4	C20	...	Brownish clay	...	...	...	...	...	...	...	...	...	...
0	3	...	...	Silty clay	...	...	...	...	...	...	...	...	...	...
2	2	C19	Not classified	Greenish clay	27·5	Good, plastic	11+	...	7	2 4 6	5 5 5	Neg. Neg. Neg.	Brown Brown Brown	Steel hard Steel hard Steel hard

0	8	W40		Brown, silty clay										
0	7			Brown, fine, sandy clay										
1	4			Lignite, lignitic shale										
1	0			Brownish, sandy clay										
21	0	W41 Selected	10	Grey, medium sandy clay	20	Short, poor	17+							

TABLE 4

Locality: southernmost part NE. Sec. 25, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
...	...	...	...	Dark, friable shale	...	...	...	...	...	...	...	...	...	...
1	7	C15	4	Grey clay	26	Good	20	...	9	2 4 6	3 3·5 4	8·3 7·2 5·8	Cream Cream Cream	Very hard Very hard Very hard
1	3	W37	...	White silt	21·2	Fairly plastic, good	27	...	...	...	...	...	...	...
1	5	C16	7	Light grey clay	25	Good	16	...	7·5	2 4 6	5 7· 7	5 Neg. Neg.	Cream Grey Grey	Steel hard Steel hard Steel hard
2	6	W38	...	White silt	20·6	Slightly plastic, fairly good	20+	...	...	...	...	...	...	...
0	4	...	...	Bluish grey clay	...	...	...	...	...	...	...	...	...	...
1	2	...	...	White, very fine sand	...	...	...	...	...	...	...	...	...	...
0	5	...	...	Pale greenish clay	...	...	...	...	...	...	...	...	...	...
0	8	C17	6	Carbonaceous clay	34·9	Good, very plastic	14	Cracked very badly	12	04 1 6	3·3 4·7 5·0	6·6 3·0 3·0	Poor, brown Brown-buff, poor Poor	Hard Hard Over fired
0	5	...	...	Light, silty clay	...	...	...	...	...	...	...	...	...	...
1	0	...	...	Fine white to cream sand	...	...	...	...	...	...	...	...	...	...
0	2	W1673	2	Brown, carbonaceous shale	31·5	Plastic, very good	31	Safe	6·6	2 6 10	6·4 6·6 8·0	13·5 13·5 8·7	Good, clean white Clean white Dirty white	Hard Hard Very hard
0	5	...	...	Lignite and shale	...	...	...	...	...	...	...	...	...	...

0	8	....	....	Brown sand.......	....	....	....	....	....	....	....	....	....	....
1	0	....	....	Lignite, lignitic shale	....	....	....	....	....	....	....	....	....	....
0	4	W1674	10	Brown, sandy clay	20·2	Short, poor.......	16	O.K........	5·4	2	1·0	13·8	Very dirty buff	Soft
										6	1·2	13·8	Very dirty	Fair
										10	1·7	8·6	Dirty grey	Hard
28	0	....		Grey, massive,.. fine to medium, sandy clay	....	....	....	....	....	....	....	....	....	....
		W36		From near top....	20	Slightly plastic, fairly good	23+	....	....	....	....	....	....	....
		W1675	10	From 6 feet below top	19·9	Short, rather poor	17+	O.K........	5·6	2	0·6	10·4	Dirty buff	Soft
										6	1·0	10·4	Dirty......	Fair
										10	2·4	7·0	Dirty grey	Hard
		W35		From near base...	22·0	Rather short	17	....	....	....	....	....	....	....

Table 5

Locality: middle of boundary between NW. Sec. 30, and SW. Sec. 30, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	...	...	Fine, white, sandy clay	...	...	...	...	...	...	...	...	...	...
1	8	W34	10	White, fine, sandy clay	17·65	Rather short, fairly good	20	...	...	...	...	...	...	...
2	6	W35a	...	Greenish white silt	...	...	...	...	...	...	...	...	...	...
4	0	...	...	Pale greenish, bluish grey clay	...	...	...	...	...	...	...	...	...	...
...	...	C14a	7	From upper 2 ft. 9 ins.	26	Good, plastic	15+	...	6·5	2 4 6	6 6 7	Neg. Neg. Neg.	Light grey Grey Dark grey	Steel hard Steel hard Steel hard
...	...	C14	7	From lower 1 ft. 3 ins.	27½	Good, plastic	13	...	7·5	2 4 6	6 6 7	Neg. Neg. Neg.	Brown Brown Brown	Steel hard Steel hard Steel hard
0	8	...	...	Brown, carbonaceous shale	...	...	13	...	...	...	...	...	...	...

Table 6

Locality: 100 yards east of middle of boundary between NW. Sec. 30 and SW. Sec. 30, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Greenish grey sand	....	....	....	....	....	....	....	....	....	....
0	7	W1666	Not classified	Dark grey clay...	30·0	Plastic, good.....	15+	....	....	....	....	....	....	....
2	0±	W1667	Not classified	Almost black clay	39·0	Plastic, fairly good	15+	....	....	....	....	....	....	....
4	0±	....	....	Carbonaceous, brown and grey, silty clay	....	....	....	....	....	....	....	....	....	....
15	0	.... W1669	Not classified	Sandy clay Taken 10 ft. down	24	Short, poor.......	13	....	....	....	....	....	....	....
....	....	W1668	Not classified	½ in. clay bed under W1669	38	Very plastic, good	12	....	....	....	....	....	....	....

TABLE 7

Locality: about west boundary of SE. Sec. 29, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	3	C8	7	Clay............	26	Good, plastic.....	26	....	6·5	2 4 6	4·5 5 6·5	12·3 6·5 3·9	Cream...... Cream...... Grey.......	Very hard Very hard Very hard
0	7	W18	....	Silty clay.........	....	....	....	....	....	....	....	....	....	....
2	9	C9	7	Clay............	25	Good, plastic.....	16+	....	7·5	2 4 6	7 7·5 8	Neg...... Neg...... Neg......	Grey....... Grey....... Grey.......	Steel hard Steel hard Steel hard
3	0	W19	9	Silty clay.........	24·7	Fairly plastic, very good	20+	....	....	....	....	....	....	....

Table 8

Locality: about northern part SE. Sec. 29, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	6	C31	7	Pale greenish clay	25	Good, plastic	16		7	2 4 6	 7 7	2·0 2·0 Neg.	Buff Grey Grey	Very hard Very hard Very hard
1	5			White sand										
2	0			Sandy clay										
1	2			Coarse and fine, sandy clay										
4	0			White, fine, sandy clay										
2	9	C30	7	Pale greenish clay	26·5	Fair, plastic	15		7·5	2 4 6	5 7 7	4·3 1·7 Neg.	Light drab Light drab Drab	Very hard Very hard Steel hard
0	3½	C29		Chocolate brown clay										
1	0			Grey silt										
0	5			Grey clay										
0	4	C28a	Not classified	Brown clay	28	Very good, plastic	16	Cracked badly	10	1½	7·3	0·67	Poor brown-buff	Hard
0	7			Brownish clay										
1	9			Silt										

Table 9

Locality: NE. Sec. 28, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
4	0	C68	7	Greenish clay.....	26·5	Good, plastic.....	17	....	8	2	4·5	6·3	White scum, grey	Very hard
										4	5·5	4·5	Grey.......	Very hard
										6	5·5	2·2	Grey	Very hard
....	6	....	....	Whitish, sandy clay	....	....	....	....	....	....	....	....	....	....

TABLE 10

Locality: northeast corner Sec. 34, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	2	W96	....	White silt........	....	....	....	....	....	....	....	....	....	....
1	7	....	....	Light grey silt....	....	....	....	....	....	....	....	....	....	....
1	2	....	....	Greenish grey, silty clay	....	....	....	....	....	....	....	....	....	....
1	0	....	....	Silty clay........	....	....	....	....	....	....	....	....	....	....
1	1	C69	7	Greenish clay.....	27	Good, plastic.....	16	....	7	2 4 6	5 7 7	4·3 1·9 Neg......	White scum, drab White scum, drab Drab.......	Very hard Very hard Very hard
3	7	....	....	Fine, white, sandy clay	....	....	....	....	....	....	....	....	....	....
1	9	C70	7	Pale green clay....	23	Good, plastic.....	14+	....	6½	2 4 6	7 7½ 7½	2·7 Neg...... Neg......	Light drab Drab....... Drab.......	Hard Very hard Very hard
0	11	....	....	Brown, carbonaceous shale	....	....	....	....	....	....	....	....	....	....
0	10	....	....	Light clay........	....	....	....	....	....	....	....	....	....	....
0	8	....	....	Black, carbonaceous shale	....	....	....	....	....	....	....	....	....	....
2	0	....	....	Grey shale........	....	....	....	....	....	....	....	....	....	....

TABLE 11

Locality: east part NE. Sec. 35, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
10	0	....	....	Dark, carbonaceous clay, shale, etc.										
		W1635	Not classified	From top.........	30	Plastic, good.....	5							
		W1636	Not classified	From near bottom	33	Plastic, somewhat tough, good	15+							
1	10	....	....	Dark brown, sandy clay, somewhat carbonaceous										
		W1637	Not classified	From middle.....	25	Short, rather poor	13							
25	0	....	....	Grey, sandy clay and sand, some clay bands										
		W1638	Not classified	From near top....	20	Very short, very poor	10+							

TABLE 12

Locality: Quarry on cone-shaped hill, near middle of NW. Sec. 36, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
4	3	W1641	3	Massive, light purplish clay	33·7	Very plastic, somewhat sticky, somewhat tough, fairly good	31	Cracked very badly	10·2	2	5·1	10·5	Good buff	Hard
										6	8·2	4·3	Some specks, clean cream	Very hard
										10	8·2	2·9	Grey-white, specks	Very hard
5	0	W1642	3	Light purplish clay	30	Very plastic, tough, good	32	Cracked....	8·3	2	4·3	11·8	Good buff	Hard
										6	6·5	8·5	Clean white, some specks	Very hard
										10	7·1	6·0	White, many specks	Very hard
1	3	W1645	8	Hard, sandy clay	21·7	Short, rather poor	30	O.K........	4·4	2	0·4	14·8	White......	Fair
										6	1·3	13·6	White, fine specks	Fair
										10	2·4	10·2	Grey-white	Hard
3	6	W1644	7	Light greenish grey clay	28·3	Plastic, good.....	19+	Safe........	7·1	04	1·5	14·2	Light buff..	Hard
										2	6·6	3·7	Fair buff...	Hard
										6	8·5	0·0	Grey.......	Vitrified
3	6	W1643	7	Light greenish clay	27·1	Plastic, good.....	18	Safe........	6·8	04	1·0	15·6	Light buff..	Hard
										2	6·0	6·3	Fair buff...	Hard
										6	8·2	0·0	Grey.......	Vitrified

Table 13

Locality: out in front of old quarry, northern part NW. Sec. 36, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	0	W1646 Selected	....	White, kaolinized silt	22	Short, rather poor	19	O.K........	5·8	05 2 6	0·0 1·0 2·0	13·5 10·7 8·0	Light cream Cream Grey buff	Soft Fair Fair
0	3	W1647...	7 indicated....	Grey shale........	33·3	Plastic, very good	16	Cracked slightly	8·3	05 2	3·7 8·3	11·3 0·0	Dark buff Poor brown-grey	Hard Hard
0	4	....	....	Lignite...........	....	....	....	....	....	....	....	....	....	....
1	6	W1648	Not classified	Brown, carbonaceous shale	33·7	Tendency to be short, fairly good	13	Safe........	8·1	05 3	3·0 8·7	14·9 4·0	Salmon Poor brown-red	Hard Hard
0	3	W1649	Not classified	Dark grey shale..	33	Plastic, good......	12	Cracked badly	9·3	05 3	3·7 7·3	8·26 0·26	Poor salmon Poor red	Hard Hard
8	0	W1650	Not classified	Dark grey and brown shale	39·5	Very poor; fairly good	12	Cracked badly	11·3	05	4·2	4·35	Poor salmon	Hard
....	....	Selected	....	....	....	....	....	....	....	4	5·0	0·12	Poor colour	Vitrified
5	0	W1651...	....	Greenish, sandy clay	....	....	....	....	....	....	....	....	....	....
				Grey sand										
....	....	W604....	....	Near middle....	....	....	....	....	....	....	....	....	....	....
....	....	W605....	....	Near middle....	....	....	....	....	....	....	....	....	....	....

Table 14

Locality: southeast corner Sec. 6, Tp. 7, Range 21, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	0+	....	....	Greyish brown clay	....	....	....	....	....	....	....	....	....	....
2	8	C500....	1	White clay........	25	Good, plastic.....	29	....	7·5	2 4 6	2 2·5 2·5	14·7 13·1 12·5	White....... White....... White.......	Hard Hard Hard
3	0	W500...	9	White, very fine, silty clay	24·4	Rather short, rather good	27+	....	....	....	....	....	....	....
1	7	....	....	White clay.......	....	....	....	....	....	....	....	....	....	....
1	7	C501...	7	Grey clay, limonite concretions	27·5	Good, plastic.....	19	....	6	2 4 6	8 9 9·5	1·2 Neg...... Neg......	Drab....... Light drab Drab.......	Very hard Very hard Very hard
9	7	W501...	9	White silt.........	24·2	Short, fairly good.	20+	....	....	....	....	....	....	....
2	4	....	....	White clay.......	....	....	....	....	....	....	....	....	....	....
5	4	....	....	Chocolate shale..	....	....	....	....	....	....	....	....	....	....
0	5	....	....	Dark, carbonaceous shale	....	....	....	....	....	....	....	....	....	....
0	1	....	....	Coal.............	....	....	....	....	....	....	....	....	....	....

Table 15

Locality: southeast corner Sec. 7, Tp. 7, Range 21, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	3			Greenish, friable shale										
0	6	W400		Greenish silt										
12	0			Fine, friable, greenish shale, rare, dark grey layers										
5	7			Dark grey to black, fine, friable shale										
0	3	W401		Fine, green sand										
2	0			Dark grey, friable shale										
1	8	C400	1	Grey clay	24·5	Good, plastic	32		7·5	2	4·5	11·5	White	Hard
										4	5	9·0	White	Hard
										6	5	8·4	White	Hard
1	0	W402	Not classified	Pale green, fine sand, very fine concretions	23	Slightly plastic	26							
0	10	C401		Pale green clay										
1	8	W403	Not classified	White to pale green silt	24	Tendency to be short, good	28							
2	1	C402	7	White to pale green silt	25	Good, plastic	18		6	2	5·5	6·7	Cream	Hard
										4	6·5	5·0	Grey	Very hard
										6	8	1·3	Grey	Very hard
0	6			Chocolate clay										
3	6	C403	7	White to pale green silt	26	Good, plastic	17		7	2	5	3·5	Drab	Very hard
										4	6	2·7	Light drab	Very hard
										6	6·5	Neg.	Drab	Steel hard
0	5			Lignite										

2	3	W404...	Not classified	Brownish silt, roots, etc.	26	Fairly plastic, good	17+	....	....	....	....	....	....	....
0	7	....	....	Grey clay........	....	....	....	....	....	....	....	....	....	....
0	6	....	....	Black, clay shale	....	....	....	....	....	....	....	....	....	....
2	5	W405...	Not classified	Silt, brown near top	21	Short, fairly good	20	....	....	....	....	....	....	....
2	7	W406...	9	Fine, grey, sandy clay	21	Short, rather poor	20	....	....	....	....	....	....	....
1	4	....	....	Grey shale........	....	....	....	....	....	....	....	....	....	....
1	7	....	....	Brown clay shale, plant remains	....	....	....	....	....	....	....	....	....	....
0	9	....	....	Coal........	....	....	....	....	....	....	....	....	....	....
1	1	....	....	Brown sand........	....	....	....	....	....	....	....	....	....	....
3	0	W407...	10	Grey, sandy clay	20	Very short, poor	14	....	....	....	....	....	....	....

TABLE 16

Locality: near boundary between NE. Sec. 15 and SE. Sec. 22, Tp. 6, Range 23, W. 3rd Mer.

Thickness		Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
Ft.	Ins.													
30	0	....	....	Lignite, shale, etc.	....	....	....	....	....	....	....	....	....	....
19	0	W1683....	3 indicated..	Whitish grey, chocolate clay, silt	32·7	Very plastic, very good	29	Cracked very badly	10·3	2	2·5	11·8	Good white	Hard
		Selected..	....	Sample from chocolate clay at top	....	....	....	....	....	6	5·2	7·5	Yellow-white, some specks	Very hard
										10	5·6	5·4	Yellow-white, many specks	Very hard

TABLE 16—*Concluded*

Locality: near boundary between NE. Sec. 15 and SE. Sec. 22, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	6	W1676	4	Brown shale	30·7	Plastic, very good	26	Safe	8·8	05	2·3	12·81	Good light buff	Hard
....	....	Selected	.....	.....	.....	.....	.....	.....	.....	2	6·4	5·0	Poor grey-buff	Hard
										6	6·6	4·5	Good clean buff	Very hard
6	0	W1678	9	White-weathering silt and clay	20·7	Rather short, rather poor	20	Safe	5·0	05	0·0	14·5	White	Soft
		Selected	.....	Silt part	.....	.....	.....	.....	.....	3	0·7	11·5	White	Soft
										6	0·9	11·5	Dirty buff	Fair
....	....	W1677	Not classified	Grey clay	28	Plastic, good	17+	Safe	7·1	05	1·3	12·85	Pinkish buff	Hard
....	....	Selected	.....	.....	.....	.....	.....	.....	.....	2	5·6	4·73	Good buff	Hard
4	0	W1679	7	Brown, fissile shale	29·3	Plastic, good	17	Very slight tendency to crack	7·4	05	2·7	14·41	Buff	Hard
....	....	Selected	.....	.....	.....	.....	.....	.....	.....	2	5·3	8·2	Fair buff	Hard
										6	7·7	2·8	Poor buff	Very hard
3	0	W1680	7	Grey shale, etc.	24·7	Plastic, good	14	Very slight tendency to crack	7·0	04	1·0	12·57	Buff	Hard
....	....	Selected	.....	.....	.....	.....	.....	.....	.....	4	5·7	2·0	Poor grey	Hard
										6	5·7	2·0	Poor	Very hard
3	0	W1681	7	Coaly shale, fissile shale	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
....	....	Selected	.....	Grey shale, with roots, sample from grey shale	33·3	Tendency to be short, fairly good	13	Safe	6·3	05	2·4	19·0	Dark buff	Hard
										3	11·5	1·3	Poor grey	Very hard
										6	11·5	0·2	Dark grey	Vitrified
5	0+	W1682	10	Sandy clay	19·9	Very short, poor	13	O.K.	4·2	04	0·0	13·65	Dirty brown	Soft
....	....	Selected	.....	.....	.....	.....	.....	.....	.....	2	0·7	12·65	Dirty brown	Soft
										6	1·3	10·85	Very dirty	Soft

TABLE 17

Locality: northern part NW. Sec. 14, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2		....	Not tested....	Dark shale.......	....	....	......	....	....	....	....	....	....	....
1	—	....	....	Sand............	....	....	......	....	....	....	....	....	....	....
				Top of Whitemud?	....	....	......	....	....	....	....	....	....	....
1	3	C71	7	Pale green clay....	24	Good, plastic.....	18	....	7	2 4 6	4 6 6	7 4·9 2·3	Dirty cream Grey....... Grey	Hard Hard Very hard
1	2	....	....	Pale green, silty clay	....	....	......	....	....	....	....	....	....	....
2	1	C71	....	Pale green clay....	....	*See* above........	......	....	....	....	....	....	....	....
1	3	....	....	Pale green, fine, sandy, silty clay	....	....	......	....	....	....	....	....	....	....
1	4	W97 ...	Not tested....	Brown, silty clay	....	....	......	....	....	....	....	....	....	....
5	9	....	....	Fine, sandy clay, pale green, silty clay	....	....	......	....	....	....	....	....	....	....
....	....	W98.... Selected	Not tested....	From near middle	....	....	......	....	....	....	....	....	....	....
3	0	C72....	7	Pale green clay....	26·5	Good, plastic.....	15+	....	8	2 4 6	7·5 8 8	Neg.... Neg.... Neg....	Light drab. Drab....... Drab.......	Very hard Very hard Very hard
2	3	....	....	Black, carbonaceous shale	....	....	......	....	....	....	....	....	....	....
3	0	....	Not tested....	Fine, brown sand.	....	....	......	....	....	....	....	....	....	....
6	0	W99....	....	Grey, sandy clay, very fine at top	....	....	......	....	....	....	....	....	....	....

Table 18

Locality: about 800 feet east of Section of Table 17

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	9		Not tested	Dark grey clay										
2	11			Light grey clay										
4	4	C67	7	Light greenish grey, silty clay	25	Fairly plastic	26		7	2 4 6	3·0 4·0 5·5	7·8 7·2 2·4	Cream Cream Grey	Hard Hard Very hard
8	0			Sandy clay										
2	3			Coaly, and brown carbonaceous sand, etc.										
			Not tested	Sandy clay										

Table 19

Locality: near boundary between Secs. 13 and 14, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	2		Not tested	Fine silt and sand										
2	3	C66	7	Greenish clay	25	Fairly plastic	14		8	2 4 6	3·5 3·5 4·0	7·7 6·8 5·7	Light brown Grey Light brown	Hard Hard Hard
3	9	W93		Fine, sandy clay										
0	6			Fine, sandy clay										
0	1			Dark brown, carbonaceous shale										
0	6		Not tested	Brown, sandy clay										
0	3			Black, carbonaceous shale										
27	0			Sandy clay										

TABLE 20

Locality: very eastern part Sec. 13, Tp. 6, Range 23, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Lignite seam.....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	Greenish sandstone	....	....	....	....	....	....	....	....	....	....
....	....	W1665 Selected	4 or 5 indicated	Dark shale, sample from base	....	Plastic, very good	30+	Safe	8·0	6	6·3	6·7	Cream, many specks	Hard
20	0+	....	Not tested....	Greenish clay, silt, etc.	....	....	....	....	....	....	....	....	....	....
		W1664 Selected	7 indicated....	Clay from near top	24	Plastic, good......	27+	Cracked slightly	6·6	05 4	1·1 4·1	11·70 4·85	Good light buff Good buff	Hard Hard
		W1663 Selected	9 indicated....	Silt from near middle	20	Fairly plastic, rather good	26+	Safe........	6·0	2 6	1·0 1·0	10·35 11·60	Dirty grey Dirty buff	Fair Hard
0	6	W1662	Not classified	Brown shale......	42	Short, poor.......	16	Safe........	5·0	6	4·6	48·6	Poor........	Punky
1	0	....	....	Coal.............	....	....	....	....	....	....	....	....	....	....
1	0	W1661	9	Fine, sandy clay..	20	Slightly plastic, fairly good	26	Safe........	6·6	6	0·7	11·26	Dirty buff	Soft
15	0	W1660	9	Fine, sandy clay, from bottom	21·7	Slightly plastic, fairly good	26	Safe........	4·8	4 10	0·3 1·9	10·15 8·48	Dirty grey Dirty grey	Hard Hard

Table 21

Locality: on nose of a high, narrow spur in western part of Sec. 18, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	....	Not tested....	Greenish, fine, friable clay	....	....	....	....	....	....	....	....	....	....
5	8	C60	4	Light and dark grey clay.......	29	Good, plastic.....	31	....	9	2 4 6	6 6·5 7	8·9 6·4 5·9	Cream...... Grey Cream......	Hard Very hard Very hard
1	6	C61	7	Light grey clay...	23	Good, plastic.....	26	....	7	2 4 6	4 6 6	7·5 4·9 3·1	Cream...... Grey....... Grey.......	Hard Very hard Very hard
5	0	C62	7	Light green, silty clay	25	Good, plastic.....	18	....	7·5	2 4 6	3·5 6 6	5·9 2·2 Neg.	Light grey. Grey....... Grey.......	Hard Very hard Very hard

Table 22

Locality: east across a coulée from preceding section. Is in SW. Sec. 18, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	0	....	Not tested....	Dark, grey-green, friable shale	....	....	......	....	....	....	....	....	....	....
4	3	C58	1	Light and dark grey clay	27·5	Good, plastic.....	31	....	7·5	2 4 6	4·0 5·5 5·5	11·6 9·9 7·9	White....... White....... White.......	Hard

7	6			Fine silt, coarser below										
		W86 Selected	9	From top	21·3	Fairly plastic, very good	27							
		W87 Selected	9 indicated	From bottom	22·4	Fairly plastic, very good	27							
2	3	W88	9	Medium, sandy clay	22	Rather short, fairly good	26+							
0	9		Not tested	Yellow, fine sand										
0	11	C56	7	Silty clay	27·3	Very good, plastic	18	Safe	7·1	04 3 6	2·1 5·3 7·0	13·47 7·62 2·04	Clean cream Clean cream Dark buff	Fine Hard Very hard
0	9			White silt										
0	2		Not tested	Silty clay										
3	11			Silty clay										
2	6	C57	7	Silty clay	28	Fairly plastic	16		8	2 4 6	5 6 7	7·7 5·1 Neg.	Cream Cream Grey	Hard Hard Very hard
1	4			Yellow-banded, silty clay										
0	10			Dark grey, silty clay										
1	6		Not tested	Dark grey, sandy clay										
1	0			Dark green, silty clay										
3	3	W89	10	Light grey, very fine, sandy clay	21	Short, fairly good	18							
2	0			Coal and coaly shale										
25	0+		Not tested	Grey, greenish, sandy clay										

TABLE 23

Locality: southeast Sec. 17, Tp. 6, Range 22, W. 3rd Mer., on east side of a coulée

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	8	....	....	Dark grey, fine silt	....	....	....	....	....	....	....	....	....	....
1	11	C51	4	Pale green, silty clay	26	Good............	26+	....	7·5	2 4 6	2 2 3	8·3 7·0 6·2	Cream...... Grey....... Buff........	Hard Hard Hard
0	4	....	....	White sand.......	....	....	....	....	....	....	....	....	....	....
0	2	....	....	Grey, silty clay...	....	....	....	....	....	....	....	....	....	....
1	4	W70	9 indicated...	Very fine, white, sandy clay	18·3	Tendency to be short, good	26	....	....	....	....	....	....	....
2	3	C50 Selected	10 indicated...	Sand and silty clay, clay sampled	22	Plastic, very good	18	....	....	....	....	....	....	....
40	0	....	....	Grey, fine, sandy clay	....	....	....	....	....	....	....	....	....	....
		W76 Selected	9 indicated...	Sampled ⅓ down..	21	Short, rather poor	27	....	....	....	....	....	....	....
		W77 Selected	9 indicated...	Sampled ⅔ down..	19·8	Rather short, fairly good	27	....	....	....	....	....	....	....

TABLE 24

Locality: east side of a long coulée, in easternmost part SE. Sec. 17, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
				Ravenscrag, greenish sand	....	....	....	....	....	....	....	....	....	....
		W1653 Selected	6 indicated...	Brown and chocolate shale, sample selected	34	Plastic, good......	16	Very badly cracked	11	6	1·6	10·9	Iron-stained buff	Soft
				Erosional unconformity	....	....	....	....	....	....	....	....	....	....
8	0+	....	....	Zone grey silt, green, purply clay	....	....	....	....	....	....	....	....	....	....
		W1654	4 indicated...	1-foot bed light green clay	31·4	Plastic, very good	18	Small crack	10	6	5·3	3·3	Grey buff...	Very hard
		W1655	2	3-inch, purplish layer	35·5	Plastic, very good	31	Very slight tendency to crack	8·3	3 6	6·0 6·2	12·4 10·9	Good white Clean white, some specks	Hard Hard
		W1656	4 indicated...	Silt bed below above	23·1	Fairly plastic, good	29	Safe........	7·3	6	1·3	11·13	Buff, fairly clean	Hard
20	0+	....	....	Massive, coarse, sandy clay	....	....	....	....	....	....	....	....	....	....
		W1657	4 indicated...	2 feet near top.....	....	....	....	....	....	....	....	....	....	....
		W1658	10 indicated...	Taken just below middle	19·6	Short, poor.......	20	Safe........	5·4	2 6 10	1·0 1·0 2·5	11·7 11·2 7·7	Dirty brown Dirty brown Dirty grey	Soft Fair Hard

Table 25

Locality: south of above, also in SE. Sec. 17, Tp. 6, Range 22, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
				Dark grey shale..	....	....	....	....	....	....	....	....	....	....
5	6	....	....	Dark grey to chocolate, arenaceous shale	....	....	....	....	....	....	....	....	....	....
13	0	W79	9	Sandy clay.......	19·3	Rather short, rather good	27	....	....	....	....	....	....	....
2	8	C54	7	Light green clay..	25	Good............	16	....	8·5	2 4 6	5·5 5·5 7·0	4·8 4·0 Neg.	Light grey Light grey Grey.......	Hard Hard Very hard
0	6	W80	9	Whitish silt.......	23	Tendency to be short, good	26	....	....	....	....	....	....	....
2	2	C54	....	Light grey clay...		*See* Above								
0	3	....	....	Brown shale, etc..	....	....	....	....	....	....	....	....	....	....
16	0	W81	9	Grey, sandy clay	21	Short, fairly good.	26	....	....	....	....	....	....	....
16	0	W82	....	Yellowish, sandy clay	....	....	....	....	....	....	....	....	....	....

TABLE 26

Locality: Sec. 21, Tp. 2, Range 9, W. 3rd Mer.

Thickness		Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
Ft.	Ins.													
		W1603	Not classified	White, sandy clay	24	Rather short, fairly good	20	....	....	....	....	....	....	....

TABLE 27

Locality: Sec. 24, Tp. 3, Range 10, W. 3rd Mer.

Thickness		Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
Ft.	Ins.													
	....	W1607	Not classified	Greenish, sandy clay, weathering white	29	Short, rather poor	14	....	....	....	....	....	....	....

TABLE 28

Locality: about SW. Sec. 8, Tp. 5, Range 4, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	4	C749	2 indicated..	Light purplish clay	32	Quite plastic......	28	Cracked slightly	8·8	....	....	....	White. Iron specks	Hard
6	6	C750	2 indicated..	Greenish and bluish clay	33	Quite plastic, somewhat tough	30	Cracked slightly	8·6	....	....	....	White. Iron specks	Hard
3	9	C751	1	Purplish grey clay	29	Quite plastic, tough	32	Satisfactory	6·7	....	....	....	White, clean	Hard
3	6	W937	1 or 2	Dark, purplish grey, hard, silty clay	30	Very plastic, very good	29	....	....	....	....	....	....	....
1	6	....	....	Light brownish, silty clay	....	....	....	....	....	....	....	....	....	....
2	9	W938	8	Fine, sandy clay..	24·2	Good, fairly plastic	30	Safe.......	5·6	1 6 10	0·5 2·1 2·9	17·2 13·9 12·4	White...... Dirty white Dirty white	Soft Fair Fair
1	8	....	....	Light greenish, hard silt	....	....	....	....	....	....	....	....	....	....
4	4	W939	....	Brownish, silty clay	....	....	....	....	....	....	....	....	....	....
1	11	W940	8	White, sandy clay	....	....	31	....	....	....	....	....	....	....

TABLE 29

Locality: SW. Sec. 15, Tp. 5, Range 4, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	2	W920	....	Greenish clay.....	....	....	....	....	....	....	....	....	....	....
0	10	C742	....	Black clay........	....	....	....	....	....	....	....	....	....	....
7	0	C740	2	Purplish clay.....	32	Rather tough.....	28	Cracked rather badly	8·3	....	....	....	White, specks	Hard
7	0	C741	2	Purplish clay.....	28	Quite plastic, somewhat tough	27+	Cracked slightly	7·2	....	....	....	White, specks	Hard
6	0	W925	8	White, sandy clay	27	Fairly plastic.....	31	Satisfactory	5·6	....	....	....	White......	Fairly hard
5	2	W926	2	White to brown, carbonaceous, fine, sandy clay, films plant debris	29·1	Plastic, very good	30+	O.K......	6·4	2	1·4	18·9	White......	Fair
										6	3·1	15·7	Rather clean white	Very hard
										10	4·4	13·2	White, specks	Very hard
1	0	W927	....	Sandy clay.......	....	....	....	....	....	....	....	....	....	....

TABLE 30

Locality: a cone-shaped butte, between NE. Sec. 27, and NW. Sec. 26, Tp. 5, Range 3, W. 3rd. Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	9	....	....	Light purplish, hard clay	....	....	....	....	....	....	....	....	....	....
1	7	W954	2	White, sandy clay, some clay bands	25	Very good, plastic	29	O.K.......	6·5	2 6 10	1 1·5 2·6	15·0 13·6 10·8	Stained white Rather clean white, specks Dirty white	Rather soft Hard Hard
1	5	....	....	Brownish silt with roots	....	....	....	....	....	....	....	....	....	....
5	6	C772	4 indicated..	Purplish grey, silty, clay roots	33	Good, plastic.....	29	Satisfactory	7·7	....	....	....	Clean light buff	Hard
1	7	....	....	Pale yellowish grey, fine, sandy clay, roots	....	....	....	....	....	....	....	....	....	....
0	2	....	....	Light purplish silt	....	....	....	....	....	....	....	....	....	....
0	8	....	....	Pale cream-grey, very fine, sandy clay	....	....	....	....	....	....	....	....	....	....
0	2	....	....	Light brownish silt	....	....	....	....	....	....	....	....	....	....
0	6	....	....	Cream-grey, fine, sandy clay	....	....	....	....	....	....	....	....	....	....
1	0	W953	Not classified.	Dark purplish brown silt	30	Fairly plastic, fairly good	30+	....	....	....	....	....	....	....
10	2	W951	....	Light grey, sandy clay	....	....	....	....	....	....	....	....	....	....
8	0	W955	....	White, sandy clay	....	Fairly plastic.....	30	....	....	....	....	....	....	....
5	0	W957	....	White, sandy clay	21·1	Fairly plastic, good	28	Safe.......	6	2 6 10	0·5 0·9 1·0	14·0 12·6 11·2	Dirty white Dirty white Dirty grey	Friable Soft Fair
3	6	W958	....	Greenish, sandy clay	20	Tendency to be short, fairly good	20	O.K.......	46	2 6 10	0·7 1·3 2·2	12·6 11·6 14·7	Dirty buff Dirty buff Dirty brown-grey	Friable Soft Fair

TABLE 31

Locality: about 200 yards south of cone-shaped butte of Table 30

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	6	....	....	Hard, green, shaly silt	....	....	....	....	....	....	....	....	....	....
1	7	W1555	2	Mauve and grey clay	30	Plastic, good......	30	Good.......	10·0	20 6 11	8·2 Broke Broke	7·8 7·2 4·7	Grey....... Grey....... Buff........	Hard Hard Very hard
8	0	W1556	2	Light and dark grey clay	....	Plastic, good......	30	Good.......	8·6	2 6 11	8·5 9·5 10·6	8·2 7·0 4·4	Grey....... Grey....... Buff........	Hard Hard Very hard
1	1	....	....	Hard, ferruginous, concretionary layer	....	....	....	....	....	....	....	....	....	....
0	8	....	....	Grey, friable clay.	....	....	....	....	....	....	....	....	....	....
2	1	W1557	2	Dark, chocolate brown, silty? clay	30	Plastic, good......	31	Good.......	8·3	2 6 11	6·3 7·3 8·0	11·0 10·7 8·6	White....... White Light cream	Hard Hard Very hard

TABLE 32

Locality: on about boundary between SE. Sec. 34 and NE. Sec. 27, Tp. 5, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	4	W949	Not classified	Brownish, silty clay	36	Plastic, very good	14	....	....	....	....	....	....	....
7	0	....	....	Greenish, dark grey clay	....	....	....	....	....	....	....	....	....	....
....	....	C769 Selected	....	From bottom.....	....	....	....	....	....	....	....	....	....	....
1	0	C770	1 or 2 indicated	Dark brown clay.	30	Plastic, good......	30+	....	....	....	....	....	....	....
9	2	....	....	Purplish clay.....	....	....	....	....	....	....	....	....	....	....
....	....	C771	....	From upper 4 ft...	....	....	....	....	....	....	....	....	....	....
2	0	W950	8	White, sandy clay	24·2	Fairly plastic, very good	30	O.K.	6	2	1·0	17·0	White, sandy	Soft
										6	2·6	14·4	Rather clean white, fine specks	Hard
										10	3·8	11·5	Dirty white	Hard

TABLE 33

Locality: in about southern part NW. Sec. 15, Tp. 5, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	3	W1558	....	Dark grey and dark brown clay	......	....	......	....	....	....	....	....	....	....
1	0	W1559	....	Green shale......	......	....	......	....	....	....	....	....	....	....
1	8	W1560	....	Grey, very fine, banded silt	31·8	Plastic, good...	11	....	....	....	....	....	....	....
0	10	W1561	....	Mottled clay......	34	Very plastic, stiff, fairly good	13	....	....	....	....	....	....	....
0	10	W1562	....	Brownish grey silt, some ferruginous concretions	......	....	3+	....	....	....	....	....	....	....
0	4	W1563	....	Black, hard clay, white spotted	......	....	29	....	....	....	....	....	....	....
2	10	W1564	Not classified	Light mauve-grey and grey clay, white spotted, some ferruginous concretions	......	....	26	....	....	....	....	....	....	....
4	10	W1565	Not classified	Sandy clay......	......	....	26	....	....	....	....	....	....	....
2	2	W1566	Not classified	Black clay, etc....	......	....	14	....	....	....	....	....	....	....
1	3	W1567	Not classified	Brown, friable shale	......	....	11+	....	....	....	....	....	....	....
1	8	W1568	Not classified	Brown, fissile shale	......	....	10+	....	....	....	....	....	....	....
2	2	W1569	Not classified	Brown, shaly silt.	......	....	9	....	....	....	....	....	....	....
2	0+	W1570	Not classified	Sandy clay......	......	....	16	....	....	....	....	....	....	....

Table 34

Locality: a little west of locality of Table 33

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	9	....	....	Black, friable shale	....	....	....	....	....	....	....	....	....	....
2	7	W1713	5	Greenish and grey clay	25·8	Plastic, good......	19	Cracked slightly	8·4	3 6 10	4·3 4·7 5·0	8·6 7·9 5·7	Dirty buff.. Dirty buff.. Poor brown	Hard Very hard Very hard
1	2	W1712	5	Grey, silty clay...	20·3	Plastic, good......	29	Cracked....	6·6	3 6 10	1·0 1·3 1·6	11·7 11·8 10·2	Clean cream Clean cream Clean cream, some specks	Hard Hard Very hard
2	10	....	....	Yellowish and grey, sandy clay	....	....	....	....	....	....	....	....	....	....
....	....	W1711 Selected	Not classified	Sample of the yellowish	18·2	Short, fairly good.	26+	O.K.	5·2	2 6	0 0	11·5 11·3	Dirty buff Dirty buff..	Soft Soft
0	8	....	....	Grey silt with selenite	....	....	....	....	....	....	....	....	....	....
....	....	W1710 Selected	5 indicated....	Sample minus selenite	21·6	Plastic, good......	19+	Cracked badly	6·3	2	1·7	10·8	Dirty buff..	Hard
1	4	W1709	Not classified	Grey clay, ferruginous	32·9	Plastic, good......	14	Cracked badly	9·4	04 3 6	5·2 7·5 7·5	6·9 0·9 0·4	Poor salmon Poor red.... Dirty red...	Hard Very hard Vitrified
0	10	W1708	6	Dark brown clay.	34·7	Very plastic, good	16	Cracked badly	9·3	04 2	4·0 6·0	9·5 4·2	Buff........ Buff........	Hard Very hard
0	3	....	....	Dark, ferruginous clay	....	....	....	....	....	....	....	....	....	....
0	10	W1707	6 indicated....	Fissile brown shale, leaves	32	Fairly plastic, good	17	Cracked badly	7·6	2	5·7	8·65	Buff........	Very hard
1	7	W1706	7	Mauve, pale brown clay	32·5	Very plastic, somewhat tough, good	17+	Badly cracked	9·2	05 2 6	2·7 6·0 6·7	10·7 4·5 0·1	Buff........ Buff........ Grey-buff..	Hard Hard Vitrified
1	6	W1705	9	Grey, sandy clay	20·3	Short, poor.......	23+	Safe........	6·3	2 6 10	0·2 0·3 0·9	12·9 12·1 9·4	Dirty buff.. Dirty buff.. Dirty grey.	Soft Soft Hard
2	6	W1704	9	Grey, sandy clay	19·6	Very short, poor..	23	O.K........	5·4	2 6 10	0 0·3 0·7	12·3 11·96 9·45	Dirty buff.. Dirty buff.. Dirty grey.	Soft Soft Hard

Table 35

Locality: just west of locality of Table 34

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	10	W1718	2	Grey, silty clay..	24·1	Plastic, good.....	29	Cracked badly	7·1	2	2·5	11·0	Clean cream	Hard
										6	3·1	9·8	Clean white, some specks	Hard
										10	3·7	7·5	Good white, some specks	Hard
0	10	...	...	Ferruginous silt...	...	...	...	...	...	...	...	...	...	...
0	8	...	...	Grey silt, ferruginous in places	...	...	...	...	...	...	...	...	...	...
		W1717 Selected	9	Grey silt part.....	17	Short, rather poor	23	Safe........	5·1	2	0	11·6	Poor grey..	Fair
										6	0	11·5	Dirty buff..	Fair
										10	0·3	9·7	Dirty grey..	Hard
2	0	...	...	Yellow stained, sandy clay	...	...	...	...	...	...	...	...	...	...
11	8	...	...	Whitish, sandy clay	...	...	...	...	...	...	...	...	...	...
		W1716 Selected	9	From top.........	20·4	Short, rather poor	27+	Safe........	5·7	2	0	13·3	Dirty white	Soft
										6	0·4	13·1	Dirty white	Soft
										10	1·0	10·4	Dirty grey	Hard
		W1715 Selected	9	From middle.....	20	Short, rather poor	27	Safe........	5·5	2	0	13·8	Dirty white	Soft
										6	0·3	13	Dirty white	Soft
										10	0·8	11·1	Dirty grey	Hard
		W1714 Selected	9	From base........	17·9	Very short, poor..	29	Safe........	5·0	3	0	12·6	Dirty buff..	Soft
										6	0	12·6	Dirty buff..	Soft
										10	1·6	10·7	Dirty grey.	Hard

TABLE 36

Locality: west of locality recorded in Table 35, and in about eastern part NE. Sec. 16, Tp. 5, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Silts, sandy clay, etc., white silt	....	....	....	....	....	....	....	....	....	....
....	....	W1721 Selected	7 Indicated	Yellow stained, hard clay	33·6	Plastic, very good	17+	Cracked....	9·8	2 6 10	7·1 7·3 5·3	0 0 0·2	Poor........ Dirty grey. Dirty dark grey, specks	Hard Vitrified Vitrified
....	....	....	....	Sandy clay.......	....	....	....	....	....	....	....	....	....	....
		W1720 Selected	4 Indicated	Purplish clay.....	31	Plastic, good.....	23+	Cracked badly	9·2	05 2 6	2·3 5·4 6·3	13·93 7·4 5·1	Light buff.. Buff........ Fair buff...	Soft Hard Hard
		W1719 Selected	9 Indicated	Sandy clay.......	21·2	Short, rather poor	28	Safe........	3·7	2 6 10	0 0·3 1·3	14·6 13·9 11·5	Dirty white Dirty white Dirty grey	Soft Fair Hard

Table 37

Locality: SE. Sec. 17, Tp. 5, Range 2, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	3	W902	Not classified	Pale yellowish green silt	30	Fairly plastic, good	14	....	....	....	....	....	....	....
0	4	....	....	Greenish clay.....	....	....	....	....	....	....	....	....	....	....
1	10	C731	2 Indicated	Pewter grey clay.	32	Fairly plastic, good	26	Cracked rather badly	8·8	....	....	....	White, specks	Hard
6	4	C730	1 Indicated	Light grey clay..	28	Very good........	30	Cracked slightly	6·8	....	....	....	White, clean	Hard
		C729	2	C729 is of entire 6 ft. 4 ins. C730 is of lowest 1 ft. plastic	26·6	Good, tough, plastic	29	Cracked slightly	7·6	1½ 3 6 10	3·4 5·3 6·5 6·8	12·65 9·64 8·0 6·0	White, specks White, specks White, many specks White, full specks	Fair Fair Hard Hard
0	5	....	....	Carbonaceous clay	....	....	....	....	....	....	....	....	....	....
3	7	C728	4	Light pinkish brown clay	28·3	Very good, plastic	26	Cracked....	8·3	1½ 6 10	3·7 4·5 4·7	8·5 6·4 4·3	Clean buff.. Clean buff.. Buff........	Hard Hard Vitrified
0	11	....	....	Dark, carbonaceous, sandy clay	....	....	....	....	....	....	....	....	....	....
4	10	W901	9	Sandy clay.......	14·2	Rather poor, tends to be short	28	Safe........	3·8	2 6 10	0·1 0·3 0·6	11·0 11·0 10·0	Dirty white Dirty white Dirty white	Soft Soft Soft

TABLE 38

Locality: SW. Sec. 23, Tp. 6, Range 2, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Chocolate brown, carbonaceous clay	....	....	....	....	....	....	....	....	....	....
1	5	W716	....	Light grey sand..	....	....	....	....	....	....	....	....	....	....
0	8	W715	....	Greenish grey, sandy clay	....	....	....	....	....	....	....	....	....	....
4	8	W714	....	Light green, sandy clay	....	....	....	....	....	....	....	....	....	....
6	0	....	....	Deep green, sandy clay	....	....	....	....	....	....	....	....	....	....
25	0	....	....	Thin-bedded, dark shale and sand	....	....	....	....	....	....	....	....	....	....

TABLE 39

Locality: about middle NW. Sec. 9, Tp. 6, Range 1, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
3	9	W854	....	Massive, grey-green sand Top Whitemud	....	....	....	....	....	....	....	....	....	....
9	5	W857	9	White, sandy clay Uppermost 8 ft. 3 ins.	32	Good, plastic.....	27	Cracked very badly	8·4	3 6 10	2·2 2·2 2·7	14 14 12·6	Dirty grey Dirty grey Dirty grey	Soft Soft Fair

TABLE 40

Locality: SE. Sec. 7, Tp. 6, Range 1, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	....	....	Dark, carbonaceous shale	....	....	....	....	....	....	....	....	....	....
0	9	W994	6	Light purplish grey, silty clay	25·4	Very plastic, good	27+	Cracked very badly	8·5	2 6 10	1·2 2·4 2·5	11·8 10·8 8·7	Clean cream Buff........ Dirty buff..	Hard Very hard Very hard
3	9	W993	6	Light grey silt....	21·1	Plastic, good.....	23+	Cracked badly	6·8	2 6 10	0 1·2 1·6	12·5 10·6 9·1	Yellow-brown Poor........ Dirty grey.	Fair Hard Very hard
2	3	W992	6	Light green clay and sandy clay	25	Plastic, good.....	23	Cracked badly, scummed	7·3	2 6 10	1·5 2·7 3·2	13·3 10·9 8·95	Yellow-brown Dirty buff.. Dirty grey.	Fair Hard Hard
10	0	W991	6	Light green, sandy clay	23·5	Plastic, good.....	20	Cracked badly	6·6	2 6 10	0·5 1·8 2·0	14·3 12·1 10·0	Dark brown Poor brown Dirtybrown	Hard Hard Hard
....	....	....	....	Lake level........	....	....	....	....	....	....	....	....	....	....

Table 41

Locality: SW. Sec. 7, Tp. 8, Range 28, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	2	....	....	Lignite..........	....	....	....	....	....	....	....	....	....	....
1	0	W1189	1 indicated..	Purplish grey clay	33·0	Very plastic.......	32	....	....	....	....	....	....	....
1	3	W1188	1	Purplish brown clay	30·8	Very plastic, tough	32	Cracked....	9·0	10	9·1	5·1	Pure white, excellent	Hard
										6	8·6	8·8	Pure white	Hard
										2	8·6	7·1	Pure white	Hard
2	0	W1186	2	Pale, mauve-grey clay, yellow stains	33·3	Plastic, very good	29	Slightly cracked	10·7	10	10·3	2·7	White, badly iron stained, specks	Very hard
										6	8·0	8·3	White, dirty	Hard
										2	6·6	10·3	Off white, dirty	Hard
3	0	W1185	2	Pale, mauve-grey clay	33·3	Very plastic, good	29	Cracked badly	10·8	10	8·0	4·5	White, bad iron specks	Very hard
										6	2·2	11·5	White, specks	Hard
										2	3·6	13·8	White, specks	Hard
1	6	W1184	2	Brownish clay....	29·6	Plastic, very good	30	Slightly cracked	9·1	10	5·5	6·6	White, iron scum	Hard
										6	4·2	11·2	Almost white, some iron scum	Hard
										2	3·4	12·2	Almost white, clean	Hard
0	9	W1183	2 indicated..	Brownish clay....	30	Plastic...........	28	....	....	....	....	....	....	....

3	0	W1190	1	Pale, mauve-green clay and silt	30·8	Plastic, very good	31	O.K.	8·4	10	6·2	8·5	Almost white, light cream, clean	Hard
										6	3·7	12·7	Almost white, clean	Hard
										2	3·0	13·7	White, clean	Hard
2	0	W1192	1	Brownish grey clay	32·0	Very good	27	O.K.	7·5	10	6·7	7·0	Light cream, clean	Very hard
										6	4·1	12·8	Almost white, clean	Hard
										2	3·3	13·9	White, clean	Hard
1	6	W1193	4	Brown, carbonaceous, silty clay	30·0	Very plastic	28	O.K.	8·8	10	4·5	10·1	Buff, specks	Hard
										6	2·9	15·0	Cream	Hard
										2	3·3	12·3	Cream, clean	Hard
1	10	W1194	2	Light grey, silty clay	28·3	Plastic, very good	31	O.K.	6·7	10	3·7	13·3	White, fine specks	Fairly hard
										6	1·4	17·6	White, clean	Fairly hard
										2	1·1	18·1	White, clean	Fairly hard
0	10	W1195	1	Light brownish grey clay	34	Very plastic	29	O.K.	8·5	10	9·2	0·56	Dark grey	Vitrified
										6	4·6	12·9	Almost pure white, clean	Hard
										2	3·8	14·7	Almost pure white, clean	Fairly hard
0	6	W1196	4	Light brown clay	32·0	Very plastic	28 +	O.K.	9·0	10	8·4	2·5	Dark grey	Vitrified
										6	5·0	11·5	Cream, clean	Very hard
										2	4·0	13·6	Cream, clean	Hard
2	6	W1197	4	Grey clay	34·3	Very plastic, fairly good	26	O.K.	10·3	10	8·4	0	Dark grey	Vitrified
										6	6·2	7·2	Buff	Hard
										2	3·7	11·9	Light cream, fairly clean	Hard

TABLE 41—*Concluded*

Locality: SW. Sec. 7, Tp. 8, Range 28, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	8	W1198	9	Light grey, sandy clay	22·0	Slightly plastic...	20	....	....	....	....	....	....	....
1	8	W1199	4	Brown, carbonaceous, silty clay	36·3	Plastic..........	25+	O.K.......	7·7	10	10·7	3·9	Dark grey..	Vitrified
										6	6·1	15·2	Buff.......	Hard
										2	3·7	20·9	Light cream, clean	Fairly hard
0	6	W1200	4	Light brownish grey, hard clay	34·6	Very plastic......	15	O.K.......	8·9	02	4·4	11·0	Cream, good	Hard
3	6	W1201	9	Grey, silty clay..	26·4	Plastic..........	20	....	....	....	....	....	....	....
0	8	W1202	Not classified	Brownish grey, hard clay	32·3	Very plastic......	14	Cracked....	9·5	02	5·7	6·7	Salmon, poor	Hard
5	6	W1203	Not classified	Grey, hard, silty clay	27	Plastic..........	14	....	....	....	....	....	....	....
1	0	W1204	Not classified	Dark brown, hard clay	30·3	Very plastic......	5	Cracked....	10·7	06	3·3	8·0	Salmon.....	Hard
										02	8·7	8·7	Salmon, poor	Rather hard
										2	7·8	0·4	Brown-red..	Very hard

Table 42

Locality: small pit, north of highway, about NE. Sec. 1, Tp. 8, Range 29, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Coal..............	....	....	....	....	....	....	....	....	....	....
0	3	W1734	....	Silty clay.........	30·7	Short, poor.......	33	Safe........	5·2	2	6·6	19·5	Buff........	Punky
										6	7·3	16·9	Dirty buff..	Fair
										10	8·4	14·9	Dirty buff..	Hard
0	4	W1733	2	Dark purplish grey clay	29·4	Fair, plastic......	30+	Cracked....	8·0	3	7·4	9·3	Fairly good white	Hard
										6	8·3	7·9	Good white, specks	Very hard
										10	8·0	5·7	Good white	Very hard
2	10	W1731	2	Grey clay, fine white specks	29·1	Very plastic, tough, fairly good	32	Cracked....	7·5	3	8·1	8·8	Good white, some specks	Hard
										6	9·0	6·3	Clean white, some specks	Very hard
										10	10·0	5·2	Good white, some specks	Very hard
1	0	....	....	Like above, but more white specks										
0	6	W1732	1	Grey clay, many white specks	32·1	Plastic, somewhat tough, greasy, good	32	Cracked very badly	8·0	2	8·8	10·5	Good white	Hard
										6	11·0	5·4	Very good white	Very hard
										10	11·3	3·3	Good white, some specks	Very hard

Table 43

Locality: SW. Sec. 3, Tp. 8, Range 29, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	6	W1205	Not classified	Light grey, sandy clay, grey clay lenses	24·0	Plastic...........	28	....	....	....	....	....	....	....
2	0	W1206	4	Light brown clay.	29·3	Very plastic......	20	Small cracks	9	10	6·6	2·2	Grey, iron scum	Vitrified
										6	5·1	7·8	White, iron scum	Hard
										2	4·9	7·8	Light cream, clean	Hard
2	2	W1207	....	Light brown, sandy clay	20	Fairly plastic, good	27	O.K.	6·2	10	2·4	8·6	White, many fine iron specks	Fairly hard
										6	1·1	11·0	White, fine specks	Fairly hard
										2	1·1	10·6	White, fine specks	Fairly hard
5	8	W1208	9	Light grey, sandy clay	22·0	Slightly plastic...	29	....	....	....	....	....	....	....
5	0	W1209	9	Light grey, very sandy clay	22·3	Slightly plastic...	23	....	....	....	....	....	....	....
4	0	W1210	9	Light grey, sandy clay	25·0	Slightly plastic...	20	....	....	....	....	....	....	....
0	8	W1211	10	Light brownish grey, very sandy clay	19·0	Slightly plastic...	14	....	....	....	....	....	....	....
3	0	W1212	10	Light grey, very sandy clay	20·0	Slightly plastic...	13	....	....	....	....	....	....	....
4	0	W1213	10	Grey, very sandy clay	23·0	Slightly plastic...	10	....	....	....	....	....	....	....

Table 44

Locality: SW. Sec. 30, Tp. 7, Range 28, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	11	....	....	Lignite........	....	....	....	....	....	....	....	....	....	....
0	2½	....	....	Brownish grey, carbonaceous silt	....	....	....	....	....	....	....	....	....	....
0	9	....	....	Lignite........	....	....	....	....	....	....	....	....	....	....
0	3	....	....	Brown clay......	....	....	....	....	....	....	....	....	....	....
1	3	W1269	2	Grey clay........	34·0	Very plastic, good	31+	Cracked badly	10·2	10	9·2	4·4	White, almost clean	Very hard
										6	8·3	8·0	White, iron stained	Hard
										2	6·8	9·4	White, iron stained	Hard
1	11	W1268	1	Pale brown clay..	32·3	Very plastic, fairly good	31+	Cracked badly	10·1	10	7·8	5·7	White, almost clean	Very hard
										6	7·6	7·7	White, clean	Hard
										2	6·5	9·1	White, clean	Fair
4	6	W1267	2	Grey clay, iron spots	28·3	Very plastic, good	31	Some small cracks	7·5	10	8·7	7·0	White, many fine specks	Very hard
										6	7·9	10·2	White, iron stained, badly specked	Hard
										2	7·2	9·7	White, iron stained, specks	Hard
2	8	W1266	3	Grey clay, iron spots	30·0	Very plastic, good	31	Some very small cracks	8·3	10	8·7	5·3	White, many fine specks	Very hard

TABLE 44—*Concluded*

Locality: SW. Sec. 30, Tp. 7, Range 28, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
										6	6·8	9·2	White, many specks	Hard
										2	6·0	10·0	White, many specks	Hard
1	10	W1265	1	Brownish grey clay	28·3	Very plastic, good	31	Some very small cracks	7·2	10	7·7	7·3	White, almost clean	Very hard
										6	5·9	10·6	Pure white	Hard
										2	4·9	11·9	Pure white.	Fair
0	9	W1280..	1	Pale brownish grey clay	30·6	Very plastic, good	30	Cracked slightly	8·4	10	7·3	0·23	Grey.......	Vitrified
										6	5·3	7·2	White.......	Very hard
										2	4·7	8·0	Light cream, clean	Fair
1	1	W1279	4	Brownish grey clay	34	Very plastic, good	29+	Cracked....	10·2	10	7·0	1·2	Grey.......	Vitrified
										6	5·6	7·3	Light cream	Very hard
										2	5·4	6·6	Cream......	Hard
4	4	....	....	Silty clay and grey clay	....	....	....	....	....	....	....	....	....	....
....	....	W1278	1 indicated....	Mostly of the clay	30·6	Very plastic, good	30	....	....	....	....	....	....	....
2	11	W1277	1 indicated....	Grey, sandy clay.	22·6	Plastic...........	30+	....	....	....	....	....	....	....
2	2	W1276	1	Grey clay.........	31·3	Very plastic, good	29	O.K.	9·1	10	6·3	6·2	Light cream	Vitrified
										6	4·1	10·7	White, clean	Very hard
										2	3·3	12·3	White, clean	Fair
2	5	W1275	2	Light grey, sandy clay	22·6	Plastic, good......	29	O.K.	5·3	10	2·3	10·8	White, fine specks	Fairly hard
										6	1·0	14·0	White, fine specks	Fairly hard
										2	0·6	14·8	White, fine specks	Fairly hard
1	4	W1274	1 indicated....	Dark grey clay, some very fine sandy clay	29	Plastic, very good	29	O.K.	8·1	10	6·2	5·1	Light grey	Vitrified
										6	3·5	11·1	White, clean	Very hard
										2	2·9	11·8	White, clean	Fair

4	8	W1273	9	Light grey, sandy clay	22·0	Slightly plastic...	28+	O.K.	5·2	10	2·0	10·6	White, fine specks	Fairly hard
										6	1·0	13·5	White, fine specks	Fairly hard
										2	0·7	14·0	White, fine specks	Fair, friable
2	6	W1272	6	Grey, silty clay... Grey, very fine, sandy, and silty clay	28·3	Very plastic, good	19	Cracked....	8·7	10	6·2	3·0	Dark grey-buff	Very hard
										6	4·1	7·8	Dark buff brownish	Hard
										2	3·4	8·5	Dark buff brownish	Fair
2	0	W1271	9	Grey, sandy clay.	25·8	Plastic...........	23	O.K.	7·2	10	4·2	7·3	Grey-buff, fine specks	Hard
										6	2·2	12·3	Dark buff brownish	Hard
										2	5·2	13·0	Dark buff brownish	Fair

Table 45

Locality: SE. Sec. 24, Tp. 7, Range 29, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	6	W1350	2	Pale brownish grey clay	33·0	Very plastic, very good	28	Badly cracked	11·4	10	6·4	5·4	White, iron-stained, somewhat dirty	Very hard
										6	5·8	7·9	White, fairly clean	Very hard
										2	5·1	7·7	White, fairly clean	Hard
1	0	W1352	3	Pale grey, iron-stained, silty clay	27·3	Very plastic, good	26	Cracked....	8·9	10	3·8	10·0	White, badly specked	Hard
										6	3·4	9·7	White, badly specked	Hard
										2	2·7	11·2	White, many fine specks	Fair

TABLE 45—*Concluded*

Locality: SE. Sec. 24, Tp. 7, Range 29, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	5	W1351	2	Pale grey, silty clay	27·3	Very plastic, good	26	Cracked....	8·7	10	2·6	10·8	White, small specks	Hard
										6	2·1	11·4	White, small specks	Hard
										2	2·0	11·4	White, small specks	Hard
3	6	W1354	....	Pale grey, sandy clay	25·6	Fairly plastic.....	29	....	....	....	....	....	....	....
5	6	W1353	9	White, sandy clay	24·3	Plastic, good.....	29	Small cracks	6·7	10	5·5	11·6	White, minute specks	Friable
										6	2·0	12·2	White, specks dirty	Friable
										2	0·6	14·8	White, specks dirty	Friable
0	3	....	....	Clay ironstone....	....	....	....	....	....	....	....	....	....	....
0	5	W1355	6	Brown, silty clay.	34·6	Plastic, good.....	23	Badly cracked	10·2	10	5·9	4·6	Yellow-brown, poor	Very hard
										6	5·0	8·3	Poor	Very hard
										2	4·3	9·6	Poor.......	Hard
1	0	W1356	4	Grey, silty clay...	30·6	Plastic, good.....	23	Cracked....	8·7	10	4·9	7·6	Light cream, good	Very hard
										6	3·3	10·8	Light cream, good	Very hard
										2	2·0	13·2	Light cream, good	Fair

TABLE 46

Locality: SE. Sec. 6, Tp. 7, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	0	W1219	2	Pale mauve-grey clay	32·3	Very plastic, good	31	Cracked....	9·7	10	8·0	6·4	White, specks	Hard
										6	5·7	10·2	White, slight specks	Hard
										2	6·5	10·6	White, slight specks	Hard
2	9	W1218	3	Light mauve-grey clay	31	Very plastic, good	31	Slightly cracked	9·4	10	9·0	3·5	White, dirty specks	Hard
										6	7·1	7·4	White, badly specked	Hard
										2	6·6	9·5	White, dirty, fine specks	Hard
3	0	W1217	2	Light mauve-grey, silty clay	30	Very plastic, good	31	Very small cracks	8·3	10	8·3	5·6	White, specks	Hard
										6	5·6	10·5	White, slightly specked	Hard
										2	4·9	12·5	White, dirty, specks	Hard
3	6	W1216	4	White, silty clay	30·3	Plastic, very good	30	Cracked....	8·6	10	6·6	3·4	Light grey, slightly specked	Very hard
										6	4·7	7·9	Cream, clean	Hard
										2	4·5	8·9	Light cream, clean	Hard
1	0	W1215	Not classified	Light grey to white clay, silty clay	28·0	Plastic..........	29	....	....	....	....	....	....	....
3	5	W1214	8	White, sandy clay	25·6	Plastic, good.....	30	O.K.......	6·4	10	2·5	12·5	White, slight specks	Hard
										6	1·3	15·4	White, clean	Fairly hard
										2	1·2	15·3	White, clean	Fairly hard

TABLE 47

Locality: Verwood trestle, south of locality of preceding table and just north of highway 13

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
3	0	W1178	4	Light grey clay	30·0	Very plastic	28+	Very small cracks	9·1	10	7·0	4·3	Grey	Vitrified
										6	4·5	10·8	Very light cream, clean	Very hard
										2	3·8	11·6	Almost white, fairly clean	Hard

TABLE 48

Locality: Sec. 7, Tp. 6, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	7	....	....	Lignite	....	....	....	....	....	....	....	....	....	....
0	3	....	....	Silt	....	....	....	....	....	....	....	....	....	....
0	8	....	....	Lignite	....	....	....	....	....	....	....	....	....	....
0	4	....	Not tested	Dark purplish grey shale	....	....	....	....	....	....	....	....	....	....
2	2	W1307	....	Light brownish, mauve-grey clay	30·0	Very plastic, good	30+	Cracked	9·1	10	8·6	4·3	Pure white, clean	Very hard
			1	....	....	....	....	....	....	6	8·2	7·0	Pure white, clean	Very hard
										2	7·3	8·0	Pure white, clean	Hard
1	4	W1306	....	Light brownish, mauve-grey clay, iron stains	32·0	Very plastic, sticky	30+	Cracked	9·5	10	7·7	5·3	White, many fine specks	Very hard
			3	....	....	....	....	....	....	6	7·2	7·1	White, many fine specks	Very hard

…			…	…	…	…	…	…	…	2	5·7	9·2	White, many fine specks	Hard
2	8	W1305..	3	Light mauve to brownish grey clay	30·3	Very plastic, good	30+	Cracked....	9·0	10	9·2	4·3	White, many specks	Very hard
										6	8·6	5·8	White, many specks	Very hard
										2	7·0	9·4	White, many specks	Hard
4	0	W1304..	3	Grey clay.........	28·6	Plastic, greasy....	30+	O.K........	8·0	10	8·5	3·5	White, iron stained, many fine specks	Very hard
…			…	…	…	…	…	…	…	6	6·9	9·0	White, iron stained, many fine specks	Very hard
…			…	…	…	…	…	…	…	2	6·5	9·7	White, iron stained, many fine specks	Fair
1	0	W1303..	Not classified	Yellow, silty clay, many minute ferruginous concretions	29·6	Plastic, very good	15	O.K........	7·8	02	5·7	9·4	Light red, fair	Hard
										6	6·4	1·8	Fair red	Hard
										2	7·3	7·0	Fair red	Hard
0	10	W1302..	1	Grey clay.........	31	Very plastic, good	30+	O.K........	8·4	10	5·6	7·2	Light cream, fairly clean	Very hard
										6	3·8	12·3	White	Very hard
										2	3·1	12·7	White	Hard
0	10	W1301..	4	Grey clay.........	29·3	Very plastic, greasy	28+	O.K........	8·2	10	7·8	0	Grey.......	Vitrified
										6	6·0	8·0	Cream......	Very hard
										2	4·2	11·0	Light cream, clean	Hard
6	6	W1300..	4	Brownish grey, silty clay	29·3	Very plastic, very good	28+	Some small cracks	9·4	10	6·5	9·4	Grey	Vitrified
										6	5·2	7·2	Cream, clean	Very hard
										2	4·7	7·7	Cream, clean	Hard

TABLE 48—*Concluded*

Locality: Sec. 7, Tp. 6, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	4	W1299..	8	Grey to white, sandy clay	23·3	Plastic, good......	30+	O.K........	7·4	10	4·0	9·2	White, somewhat dirty, fine specks	Hard
										6	3·0	11·9	White, somewhat dirty, fine specks	Hard
										2	2·7	12·3	White, somewhat dirty, fine specks	Fair
2	5	W1298..	9	Grey to white, sandy clay	23·3	Fairly plastic.....	28+	....	....	....	....	....	....	....
1	5	W1297..	9	Grey to white, sandy clay	21·6	Slightly plastic...	28+	....	....	....	....	....	....	....
2	4	W1296..	9	Grey to white, sandy clay	21·6	Slightly plastic...	28	2–3 small cracks	6·6	10	1·7	9·9	Buff, dirty	Friable
										6	0·9	12·3	Buff, dirty	Friable
										2	0·7	12·5	Buff, dirty	Friable

Table 49

Locality: about SE. Sec. 9, Tp. 6, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	9			Lignite and lignitic shale										
0	8			Brown silt										
0	11			Lignite										
0	4	W1535		Dark purplish brown, carbonaceous shale	30+									
1	6	W1536		Light mauve-grey clay, fairly clean	31+									
0	6			Yellow, highly ferruginous clay										
4	2	W1537		Somewhat ferruginous, grey clay	28									
1	6	W1538		Dark grey, slightly ferruginous clay	30+									

TABLE 50

Locality: near centre Sec. 27, Tp. 3, Range 24, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	3			Lignite and lignitic shale										
0	4	W1502	Not classified	Shale			13−							
0	4			Black, lignitic shale										
0	2		Not tested	Shale										
0	6			Lignite										
7	0	W1167	2	Pale brownish, mauve-grey clay	28·3	Very plastic, good	32	Cracked slightly	8·5	10	8·0	6·7	White, specks	Hard
										6	6·2	10·7	Pure white, slightly specked	Hard
										2	6·2	11·6	Pure white, slightly specked	Hard
0	6	W1500	2	Dark, coaly shale			32+							
1	6	W1166	2	Very dark, carbonaceous clay	36·6	Fairly plastic, fair	31	Cracked slightly	7·5	10	8·2	14·3	White, specks	Hard
										6	7·0	17·5	Pure white, slightly specked	Hard
										2	7·5	17·2	Pure white, slightly specked	Hard
4	0	W1165	6	Dark brown, very fine, sandy clay, bands white silt	24·3	Fairly plastic, tough, fairly good	26	O.K.	7·3	10	2·0	15·4	Dark grey, buff, specked	Very hard
										6	1·7	18·7	Buff, dirty	Very hard
										2	1·3	18·5	Buff, dirty	Very hard

3	6	W1164..		4	Light brownish, somewhat silty clay	29·3	Plastic, very good	20	O.K........	8·3	10	6·3	5·4	Dark grey, buff	Very hard
											6	4·3	10·5	Light cream, clean	Hard
											2	3·1	13·3	Light cream, clean	Hard
0	6	W1163		4	Brownish, grey clay	33·3	Very plastic, very good	20	O.K........	9·5	10	7·1	1·15	Dark grey, good	Vitrified
											6	5·3	7·6	Cream, clean	Very hard
											2	3·7	11·7	Cream, clean	Very hard
1	1	W1162		4	Light brown clay	29·3	Plastic, very good	17	Cracks slightly	9·0	10	6·9	0·04	Dark grey, good	Vitrified
											6	5·9	7·3	Cream, clean	Very hard
											2	4·2	10·8	Cream, clean	Very hard
4	0	W1168		9	Light grey, sandy clay	22·6	Slightly plastic...	29	....	....	....	....	....	....	....
4	6	W1169		9	Light grey, sandy clay	22·3	Slightly plastic...	29	....	....	....	....	....	....	....
3	2	W1170		9	Grey, coarse, sandy clay	23·3	Slightly plastic...	29	....	....	....	....	....	....	....
4	8	W1171		9	Light grey, sandy clay	22·3	Slightly plastic...	28	....	....	....	....	....	....	....

TABLE 51

Locality: 150 feet east of locality of Table 50

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
5	8	W1175	9	Very fine, sandy clay	25	Fairly plastic, slightly short, good	29	Some small cracks	6·8	10	6·0	10·8	White, somewhat dirty	Hard
										6	1·4	14·5	White, somewhat dirty, fine specks	Hard
										2	0·8	15·3	White, fairly clean	Hard
3	0	W1174	9	Coarse, sandy clay	22·6	Slightly plastic...	29	....	....	....	....	....	....	....
0	8	W1173	6	Chocolate, silty clay	27·9	Plastic, very good	23	Some small cracks	8·4	10	6·3	2·5	Dark grey..	Vitrified
										6	4·2	9·5	Dark buff..	Hard
										2	3·0	11·0	Dark buff..	Hard
2	2	W1172	10	Fine, sandy clay..	24·5	Fairly plastic, somewhat short, good	19	Cracked slightly	6·3	10	5·1	5·6	Dark grey, fine specks	Very hard
										6	3·0	12·5	Dark buff..	Hard
										2	1·9	14·8	Reddish buff	Hard

TABLE 52

Locality: about SE. Sec. 20, Tp. 3, Range 24, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	6	W1503	1 Indicated	Light mauve, brownish clay, rare coaly streaks	....	....	31+	....	....	....	....	....	....	....
1	8	W1504	2 Indicated	Grey clay, minute, spherical, ferruginous concretions	....	....	31+	....	....	....	....	....	....	....

TABLE 53

Locality: NE. Sec. 24, Tp. 3, Range 25, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	5	W1465	Not classified	Bentonite........	61·6	Tough, very sticky	8	....	....	....	....	....	....	....
0	3	....	....	Lignite..........	....	....	......	....	....	....	....	....	....	....
0	9	....	....	Brown, fissile shale	....	....	......	....	....	....	....	....	....	....
0	3	....	....	Lignite..........	....	....	......	....	....	....	....	....	....	....
0	4	....	....	Brown to black, carbonaceous shale	....	....	......	....	....	....	....	....	....	....
1	2	W1464	1	Greyish brown clay	29·7	Very plastic, fairly good	31	Very badly cracked	10·4	10	5·9	7·6	White, some specks	Very hard
										6	5·1	9·2	White, clean	Very hard
										2	4·0	11·3	White, clean	Hard
1	5	W1463	1	Grey clay........	29·0	Very plastic, good	31	Badly cracked	9·5	10	6·4	6·7	White, rather clean, stained	Very hard
										6	4·4	10·9	White, clean	Very hard
										2	3·4	13·1	....	....
1	9			Light grey, silty clay, partly ferruginous										
		W1462	Not classified	From non-ferruginous part	28·6	Plastic...........	31	....	....	....	....	....	....	....

Table 54

Locality: about middle of Sec. 25, Tp. 3, Range 25, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	....	....	Lignite..........	....	....	....	....	....	....	....	....	....	....
1	1	W1461	2	Dark brown, carbonaceous, ferruginous clay	31	Plastic, stiff, good	31	Badly cracked	7·5	10	5·9	16·8	Light cream, fine specks	Very hard
										6	4·8	19·0	White, fine specks	Very hard
										2	5·2	19·0	White, fine specks	Hard
0	6	W1460	2	Brown clay.......	28·6	Plastic, stiff, good	31	Very badly cracked	9·2	10	5·2	10·3	Light cream, fine specks	Very hard
										6	4·2	12·6	White, rather clean	Very hard
										2	4·3	11·7	White, rather clean	Hard
2	5	W1450	2	Grey clay, some ferruginous concretionary lenses	25	Plastic, stiff, good	29+	Very badly cracked	8·0	10	3·2	10·6	Light cream, fine specks	Very hard
										6	2·1	12·0	White, fairly clean	Hard
										2	1·6	12·7	White, fairly clean	Hard
3	8	W1458	2	Pale greyish green clay, ferruginous lenses	29·3	Very plastic, good	30	Cracked badly	9·7	10	5·6	5·7	Grey, fine specks	Vitrified
										6	3·8	9·7	White, fine specks	Very hard
										2	3·7	9·9	White, fine specks	Hard
1	5	W1457	2	Pale greyish green, silty clay, ferruginous	29·6	Very plastic, good	26	Cracked badly	9·7	10	7·6	0·6	Grey, fine specks	Vitrified
										6	5·0	8·9	White, fine specks	Very hard
										2	4·6	8·9	White, fine specks	Hard
0	9	W1456	5	Greyish green clay, ferruginous lenses	29·3	Very plastic, good	29	Cracked very badly	11	10	6·8	1·3	Dark grey, fine specks	Vitrified

										6	5·5	5·5	Buff, rather dirty	Very hard
										2	5·5	5·2	Buff, somewhat iron stained	Hard
1	5	W1455	3	Pale greenish grey, silty clay, dark streaks	30·3	Very plastic, very good	29	Badly cracked	9·1	10	5·7	6·5	Light cream, fine specks	Very hard
										6	3·8	11·1	White, many specks	Very hard
										2	3·9	10·4	White, many specks	Very hard
1	7	W1454	5	Pale brownish grey, silty clay	32·6	Very plastic, good	26	Badly cracked	10	10	7·5	0·3	Dark grey	Vitrified
										6	5·4	6·8	Buff, fairly clean	Very hard
										2	5·5	6·0	Buff, iron stained	Hard
0	8	W1453	4	Grey, silty clay	34·0	Very plastic, stiff	29	Slightly cracked	9·3	10	7·2	4·7	Grey.......	Vitrified
										6	5·4	10·4	Cream, rather clean	Very hard
										2	5·0	10·0	Cream, rather clean	Hard
0	8	....	Not tested...	Brown, carbonaceous, lignitic shale										
1	9	W1452	6	Brown, silty clay.	32·3	Plastic, good.....	27	Slightly cracked	8·8	10	6·5	5·8	Grey.......	Vitrified
										6	4·2	14·1	Buff, rather dirty, specks	Very hard
										2	4·2	12·1	Dirty buff, many specks	Hard
0	6	W1450	5	Brownish grey, silty clay	25	Very plastic, good	26	Badly cracked	9·0	10	4·9	3·6	Grey, specks	Vitrified
										6	2·9	9·9	Buff, rather clean	Very hard
										2	2·2	7·7	Buff, somewhat dirty, specks	Hard
0	3	....	....	Fine, sandy clay	....	....	....	....	....	....	....	....	....	....
0	1	....	Not tested...	Hard, purplish silt	....	....	....	....	....	....	....	....	....	....

TABLE 54—*Concluded*

Locality: about middle of Sec. 25, Tp. 3, Range 25, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	7	W1451	3	Dark grey, sandy clay	27·3	Plastic, good	30	Slightly cracked	8·3	10	4·3	8·9	Light cream, fine specks	Hard
										6	2·3	14·0	White, many fine specks	Hard
										2	2·3	11·6	White, many fine specks	Fair
0	1	....	....	Purplish shale	....	....	....	....	....	....	....	....	....	....
0	1	....	....	Fine, grey, sandy clay	....	....	....	....	....	....	....	....	....	....
0	4	....	Not tested	Lignite and lignitic shale	....	....	....	....	....	....	....	....	....	....
0	8	W1449	Not classified	Brown, carbonaceous, lignitic, silty clay	36·6	Slightly plastic	17	....	....	....	....	....	....	....
1	5	W1448	Not classified	Brownish clay	34	Plastic, tough, good	16	Slightly cracked	10·6	02	5·4	11·1	Poor buff	Hard
										6	5·7	12·0	Salmon	Hard
										2	7·0	7·4	Salmon, poor	Hard
1	5	W1447	Not classified	Very dark grey clay, films fine, white sand	34·3	Very plastic	17	....	....	....	....	....	....	....
6	2	W1446	....	Light grey, sandy clay	21·0	Slightly plastic	23	....	....	....	....	....	....	....
0	5	....	Not tested	Finely banded silt, carbonaceous films	....	....	....	....	....	....	....	....	....	....
0	3	W1445	Not classified	Brownish clay, fine ferruginous concretions	40·3	Very plastic	14	....	....	....	....	....	....	....
0	5	....	Not tested	Finely banded, coarse silt	....	....	....	....	....	....	....	....	....	....
5	8	W1444	10	Grey, sandy clay	23	Short	15	....	....	....	....	....	....	....

TABLE 55

Locality: SW. Sec. 2, Tp. 4, Range 25, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Lignite..........	....	....	......	....	....	....	....	....	....	....
10	0	....	Not tested...	Dark plastic clay, shale	....	....	......	....	....	....	....	....	....	....
2	0	W1378	4	Silty clay, a few ferruginous concretions	26·2	Plastic, very good	26	Cracked badly	8·9	10	5·4	3·2	Light grey, fairly clean	Vitrified
										6	2·7	8·7	Light cream, clean	Very hard
										2	2·5	9·2	Light cream, clean	Hard
1	9	W1377	9	Grey, fine, sandy clay, some small ferruginous spherules	20·6	Slightly plastic...	26	....	....	....	....	....	....	....
4	0	W1375	5	Grey clay, ferruginous spherules	28·3	Very plastic, very good	20	Badly cracked	8·0	10	6·2	3·8	Light grey, good	Vitrified
										6	2·8	11·9	White, fairly clean	Very hard
										2	2·4	12·7	Light cream, some fine specks	Hard
1	8	W1374	4	Pale, purplish, silty clay	27	Very plastic	28	Badly cracked	8·5	10	5·3	5·7	Grey, some yellow	Vitrified
										6	4·0	9·3	Buff, fairly clean	Very hard
										2	1·5	13·1	Light cream, good, clean	Hard
0	10	W1373	9	White, fine, sandy clay	21·6	Slightly plastic...	26	....	....	....	....	....	....	....
2	3	W1372	9	White clay, etc...	19	Short............	26	....	....	....	....	....	....	....
2	0	W1370	Not classified	Light brown clay	32	Plastic..........	26	....	....	....	....	....	....	....
0	9	W1371	5	Fissile clay, leaves	32·6	Plastic, very good	20	Slightly cracked	8·7	10	8·5	0·82	Grey, good	Vitrified
										6	5·6	8·7	Buff, fairly clean	Very hard
										2	5·7	9·0	Off buff, poor	Hard

TABLE 56

Locality: Sec. 14, Tp. 3, Range 23, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1473	1	Light brown clay	30·8	Plastic, stiff, fairly good	32	Very badly cracked	11·6	10	7·4	4·7	White, rather clean	Very hard
										6	6·8	6·3	White, clean	Very hard
										2	5·8	8·2	White, clean	Hard

TABLE 57

Locality: NE. Sec. 15, Tp. 3, Range 23, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1475	2	Greyish brown clay	26·6	Plastic, good.....	31	Slightly cracked	8·1	10	6·8	6·4	White, specks	Hard
										6	6·2	8·2	White, specks	Hard
										2	3·5	12·3	White, specks	Hard

TABLE 58

Locality: boundary between SW. Sec. 22 and NW. Sec. 15, Tp. 5, Range 28, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
				Yellowish green silt										
1	2	W1076	Not classified	White and dark purplish brown, silty clay	25	Very plastic, very good	14	Cracked badly	9·3	04	0·6	11·0	Light salmon	Hard
										2	1·0	9·5	Salmon.....	Hard
										6	3·6	4·3	Poor........	Very hard
1	10	....	....	Pale greenish cream clay										
0	8	....	....	Green clay.......	....	....	....	....	....	....	....	....	....	....
5	1	W1075	Not classified	Cream-weathering green clay	35	Very plastic, good	9	Cracked very badly	10·8	08	1·0	13·3	Light brown, salmon	Fair
										06	2·2	11·4	Light brown, salmon	Hard
										04	4·4	5·6	Salmon.....	Hard
0	7	....	....	Purplish clay.....	....	....	....	....	....	....	....	....	....	....
1	8	W1074	Not classified	Greenish grey silty clay	28·3	Very plastic, good	18	Cracked very badly	9·2	04	1·4	8·6	Dark buff..	Hard
										2	1·8	7·4	Salmon.....	Hard
										6	3·5	5·0	Fairly good, red	Very hard
3	10	W1073	1 indicated..	Purplish clay.....	31	Quite plastic, tough, very good	30	Satisfactory	7·6	....	....	....	Almost white	Hard
1	4	W1072	4 indicated..	Greenish clay, mottled purplish	28	Quite plastic, very good	26	Satisfactory	7·3	....	....	....	Buff........	Hard
1	2	W1071	7	Greenish clay, mottled yellow, etc.	30·4	Plastic, very good	16	O.K........	8·3	04	3·5	10·8	Poor buff...	Hard
										2	6·5	3·3	Poor brown	Hard
										6	7·9	0·7	Poor........	Very hard

TABLE 58—*Concluded*

Locality: boundary between SW. Sec. 22 and NW. Sec. 15, Tp. 5, Range 28, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	1	W1070	7	Brownish clay....	30	Very plastic, very good	23+	Cracked slightly	9·7	04 2 6	3·0 4·0 7·8	14·1 11·5 0·3	Light buff.. Pink-buff... Poor brown	Hard Hard Vitrified
5	0	W1064	....	Grey, very fine sand, silt										
5	6	W1063	9	White, sandy clay	....	Fairly plastic.....	27	....	....	....	....	....	....	....

TABLE 59

Locality: northern part SE. Sec. 14, Tp. 5, Range 28, W. 2nd Mer. (*See also* Table 62)

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Lignite..........	....	....	10	....	....	....	....	....	....	....
0	10	W1544	....	Grey and light brownish shale										
0	2	....	....	Lignite..........	....	....	15	....	....	....	....	....	....	....
1	8	W1542	....	Brownish clay, grading down into green clay	....	....	4	....	....	....	....	....	....	....
2	0	W1543	....	Green clay.......	....	....	....	....	....	....	....	....	....	....
0	½	....	....	Black clay.......	....	....	15+	....	....	....	....	....	....	....
0	11	W1540	....	Pale grey clay....	....	....	6	....	....	....	....	....	....	....
2	6	W1541	....	Green clay.......	....	....	....	....	....	....	....	....	....	....
3	4	W1539	4	Dark mauve or brownish to black clay	30	Good............	28	Good.......	11·3	2 6 11	4·9 5·1 4·0	9·5 8·5 6·3	Light cream Light cream Cream......	Hard Hard Very hard

Table 60

Locality: about SW. Sec. 7, Tp. 5, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
6	6	W1545	1	Greenish grey clay Black and mottled clay	28+	Good	30+	Good	11·6	2	4·9	9·5	White	Hard
										6	5·1	8·5	Greasy white	Hard
										11	4·0	6·3	Light grey	Hard

Table 61

Locality: NE. Sec. 4, Tp. 5, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1324	Not classified	Grey and yellowish, sandy clay	23·3	Slightly plastic	14	....	....	....	....	....	....	....
3	8	W1323	1	Dark brownish grey clay	30·0	Plastic, greasy, tough, good	30	Cracked badly	9·5	10	6·8	6·4	White, iron stained	Very hard
										6	4·8	11·1	White, clean	Very hard
										2	4·8	10·8	White, clean	Hard
1	9	W1322	9	Pale grey to white, mottled, sandy clay	24·3	Fairly plastic	28+	O.K.	6·8	10	5·2	11·7	White, sandy, slight specks	Hard
										6	0·7	14·8	White, sandy, slight specks	Hard
										2	0·5	14·8	White, sandy, slight specks	Fair

TABLE 61—*Concluded*

Locality: NE. Sec. 4, Tp. 5, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	...	...	Light grey clay, yellowish at top	...	...	...	...	...	...	...	...	...	...
		W1321	Not classified	Grey clay, part only	32·6	Very plastic......	23	...	...	...	...	...	...	...
0	6	...	Not tested....	Brown, carbonaceous, coaly shale	...	...	...	...	...	...	...	...	...	...
3	6	W1320	9	Light grey, sandy clay	21	Short............	23	...	...	...	...	...	...	...
0	9	...	Not tested...	Fine, banded silt, some grey shale	...	...	...	...	...	...	...	...	...	...
0	8	W1319	6	Light brownish grey clay	30·6	Very plastic......	14	O.K........	5·8	2	8·0	6·9	Poor buff...	Hard
										02	8·3	8·5	Dark cream, fair	Very hard
										6	9·6	5·3	Poor buff...	Very hard
0	9	...	Not tested....	Coal, brown, carbonaceous shale	...	...	...	...	...	...	...	...	...	...
1	0	W1318	6	Light brown clay	30·0	Very plastic, good	14	O.K........	8·5	2	6·0	5·8	Iron stained buff	Hard
										02	5·9	7·5	Cream, greenish	Hard
										6	7·6	2·0	Dirty buff	Very hard

TABLE 62

Locality: 100 yards east of locality of Table 59

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
...	...	...	...	Green clay........	...	...	...	...	...	...	...	...	...	...
0	2	...	...	Chocolate clay...	...	...	...	...	...	...	...	...	...	...
0	4	...	...	Whitish weathering clay	...	...	...	...	...	...	...	...	...	...
2	5	...	...	Green clay........	...	...	...	...	...	...	...	...	...	...

3	0	W1089		2	Purplish brown clay	39·5	Very plastic, good	31	Cracked....	10	04 2 6	2·6 3·0 7·6	16·6 15·1 5·6	Clean, white Light cream Clean, white, slightly iron-stained	Hard Hard Very hard
1	5	W1090		5	Pale green-grey, mottled, silty clay	28·9	Plastic, very good	26	Very small cracks	8·3	2 6 10	1·4 4·1 4·7	13·5 8·6 6·3	Clean cream Buff, specks Buff, many specks	Hard Very hard Very hard
0	9	....	....	......	Yellow-stained clay	....	....	....	....	....	....	....	....	....	....
1	4	W1091		5	Pale green, silty clay	26	Plastic, very good	23	Safe........	8·4	04 2 6	0·6 0·9 3·1	14·1 13·2 8·8	Clean cream Clean cream Buff........	Fair Hard Very hard
1	8	W1092		7	Light grey clay..	31·2	Very plastic, very good	14	Safe........	8·6	04 2 6	2·8 3·6 8·1	11·3 8·0 0·2	Poor brown Yellow-brown Poor........	Hard Hard Very hard
0	1	....	....	......	Dark purplish clay	....	....	....	....	....	....	....	....	....	....
1	2	W1094		7	Light brownish grey clay	31·4	Very plastic, good	14	Cracked slightly	9·2	04 2	2·6 6·0	11·1 3·6	Light buff.. Poor brown	Hard Hard
0	4	....	....	......	Dark brownish purple clay	....	....	....	....	....	....	....	....	....	....
0	9	....	....	......	Brownish green clay	....	....	....	....	....	....	....	....	....	....
0	5	....	....	......	Black, lignitic clay	....	....	....	....	....	....	....	....	....	....
2	6	W1093 Selected	....	......	Brownish, greenish clay, leaves, ferns	....	....	....	....	....	....	....	....	....	....
0	7	....	....	......	Like above, but darker	....	....	....	....	....	....	....	....	....	....
1	4½	....	....	......	Lignite..........	....	....	....	....	....	....	....	....	....	....

TABLE 63

Locality: about SW. Sec. 3, Tp. 5, Range 27, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
...	...	...	Not tested...	Lignite and lignitic shale	...	...	...	...	...	...	...	...	...	...
0	8	W1330	7	Brownish grey, mottled clay	33·0	Very plastic, sticky, very good	15	O.K.	9·0	2	9·0	0·2	Grey-brown, poor	Vitrified
										02	7·2	4·0	Dark cream	Hard
										6	9·6	0·39	Grey-brown, poor	Very hard
0	2	...	...	Lignite, etc.	...	...	...	...	...	...	...	...	...	...
4	5	W1329	Not classified	Dark grey clay...	34·0	Very plastic, good	9	Cracked....	10·1	2	6·9	0·16	Chocolate..	Vitrified
										02	9·0	0·16	Brown.....	Very hard
										06	2·2	10·9	Salmon.....	Very hard
0	9	W1328	Not classified	Dark grey to black clay	35·6	Plastic, tough....	11	O.K.	9·5	02	10·7	0·4	Poor brown	Hard
										2	10·8	0·3	Chocolate..	Vitrified
										6	11·3	0·3	Brown-red..	Very hard
0	10	W1327	Not classified	Grey clay........	31·6	Very plastic, tough	13	O.K.	8·9	02	9·1	0·28	Poor brown	Hard
										2	8·3	2·7	Brown-red, poor	...
										6	10·1	0·12	Chocolate..	Very hard
0	6	W1326	4	Light brownish grey clay	24·0	Plastic, very good	13	O.K.	6·6	02	3·3	8·8	Cream, very good	Hard
										2	2·8	9·2	Buff, good..	Fair
										6	4·4	6·6	Dark buff..	Hard
1	1	W1325	Not classified	Grey, somewhat mottled clay	30·0	Very plastic, good	12	Cracked badly	10·0	02	5·4	4·0	Salmon, poor	Hard
										2	5·6	1·97	Brown-red, fair	Very hard
										6	6·5	0·24	Brown-red..	Very hard
1	0	...	...	Lignite........	...	...	...	...	...	...	...	...	...	...

TABLE 64

Locality: NW. Sec. 5, Tp. 4, Range 26, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	10	W1262	3	Pale, mauve-grey clay	24·0	Very plastic, very good	27+	Cracked slightly	8·1	10	4·8	9·7	White, specks	Very hard
										6	3·2	11·9	White, many specks	Very hard
										2	3·1	12·1	White, many specks	Very hard
2	0	W1261	6	Grey clay.......	28·6	Very plastic, very good	26	Some very small cracks	8·5	10	8·0	3·0	Grey-cream, many specks	Very hard
										6	5·9	8·6	Cream, many specks	Hard
										2	5·3	9·6	Cream, many specks	Hard
2	10	W1260	4	Grey, partly mottled clay	23·3	Plastic...........	19	O.K........	6·1	10	5·5	5·4	Cream, some specks	Very hard
										6	1·6	12·4	Cream, clean	Hard
										2	0·9	12·6	Cream, clean	Fair
3	7	W1259	4	Light purplish and yellowish grey, silty clay	21·6	Plastic, good.....	23	O.K........	6·6	10	2·4	8·2	Cream, slightly dirty, fine specks	Hard
										6	0·4	12·5	Cream, clean	Hard
										2	0·1	12·8	Cream, clean	Fair
2	9	W1258	4	Light brownish grey clay	28·6	Very plastic......	28	O.K........	8·0	10	6·3	4·2	Cream, clean	Very hard
										6	2·9	11·9	Almost white, clean	Hard
										2	2·5	12·5	Almost white, clean	Fair
1	0	W1263	4	Brown, hard, silty clay	23·3	Slightly plastic, fairly good	20	O.K........	5·7	10	4·7	7·6	Grey.......	Very hard
										6	1·1	15·6	Buff, clean	Hard
										2	0·9	16·0	Buff, clean	Hard

TABLE 65

Locality: NE. Sec. 5, Tp. 4, Range 26, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
3	6	W1317	Not classified	Very calcareous, light yellowish green clay	30·3	Plastic...........	2	....	....	....	....	....	....	....
4	0	W1316	4 indicated	Light purplish grey, silty clay	24·0	Plastic...........	23	....	....	....	....	....	....	....
5	4	W1315	9 indicated	Grey and yellowish grey, sandy clay	20·0	Slightly plastic...	23	....	....	....	....	....	....	....
7	9	W1314	9 indicated	Pale purplish grey, sandy clay	19·0	Short............	23	....	....	....	....	....	....	....

TABLE 66

Locality: about NE. Sec. 33, Tp. 3, Range 26, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
3	6	W1257..	4 indicated	Grey and yellowish grey, silty clay	22·6	Plastic, very good	20+	O.K.......	7·2	10	1·5	10·4	Cream, fine specks	Hard
										6	0·7	12·5	Almost white, some iron specks	Hard
										2	0·4	12·2	Almost white, fairly clean	Fair

2	10	W1256..	2	Pale grey to white, sandy clay	25·0	Fairly plastic.....	27	O.K........	7·2	10	3·1	95	Light cream, fine specks	Hard
										6	2·0	12·9	White, fine specks	Fair
										2	1·2	13·0	White, fine specks	Fair
3	0	W1255 .	4 indicated...	Dirty grey clay...	27·0	Plastic...........	23	O.K........	7·6	10	4·3	7·6	Buff, fine specks	Hard
										6	2·9	11·7	Almost white, clean	Hard
										2	2·9	11·7	Almost white, clean	Fairly hard
1	8	W1254..	1	Pale purplish and yellowish clay	28·0	Very plastic, good	28+	O.K.......	7·8	10	8·4	0	Dark grey..	Vitrified
										6	5·9	13·5	Almost white, clean	Hard
										2	4·8	8·2	Almost white, clean	Fairly hard
5	1	W1253..	4 indicated...	Light grey, yellowish in places, clay	29·0	Rather plastic, very good	23	O.K........	8·5	10	6·8	1·37	Dark grey, specks	Vitrified
										6	4·2	8·5	Almost white, clean	Hard
										2	3·2	10·1	Almost white, clean	Fairly hard
1	11	W1252..	4	Pale greenish grey clay	29·0	Very plastic, good	23	O.K........	8·0	10	7·9	0·1	Dark grey..	Vitrified
										6	5·3	5·7	Cream, clean	Hard
										2	4·8	7·8	Cream, clean	Fairly hard
0	4	W1251..	Not classified	Grey clay.........	32·1	Very plastic......	29	....	....	....	....	....	....	....
1	2	W1250..	4	Dirty white clay, some ferruginous spherules	27	Plastic, very good	18	O.K........	6·5	10	7·8	0·04	Dark grey..	Vitrified
										6	5·6	6·7	Cream, clean	Hard
										2	3·0	11·2	Light cream, clean	Fairly hard
0	2	....	Not classified	Purplish brown, silty clay	......	....	....	....	....	....	....	....	....	....

TABLE 66—*Concluded*

Locality: about NE. Sec. 33, Tp. 3, Range 26, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	8	W1249..	9	Light grey to white, sandy clay	21·6	Slightly plastic, good	26	O.K........	4·6	10	1·1	11·3	Dirty white, very sandy	
										6	0·2	13·8	Dirty white	
										2	0	13·6	White, dirty specks	
0	4	....	....	Yellowish banded clay	....	....	....	....	....	....	....	....	....	....
1	0	W1248..	4	Light grey and green, film-banded clay	31·6	Plastic, very good	16	O.K........	8·0	02	6·0	6·7	Cream, very good	Hard
										2	5·5	7·7	Buff, clean	Fairly hard
										6	5·8	5·3	Buff, clean	Hard
0	10	W1247 .	Not classified	Dirty mauve-grey clay	32·6	Very plastic.......	15	....	....	....	....	....	....	....
0	4	....	Not tested....	Dark grey silt, light silt bands	....	....	....	....	....	....	....	....	....	....
0	6	W1246..	10	Light grey, silty clay	25·4	Slightly plastic....	19	....	....	....	....	....	....	....
1	1	W1245 .	4	Very fine banded, bluish grey and light grey clay	27·6	Plastic, very good	18	O.K........	8·4	10	5·8	2·2	Dark grey	Vitrified
										6	2·4	9·8	Cream, clean	Hard
										2	2·1	11·4	Cream, clean	Soft
2	4	W1244..	9	Light yellowish grey, sandy clay	22·6	Slightly plastic....	23	O.K........	5·0	10	1·4	10·3	Cream, very sandy	Fairly hard
										6	0·3	13·8	Cream, very sandy	Fair
										2	0·05	13·4	Buff........	Fair

TABLE 67

Locality: NE. Sec. 5, Tp. 4, Range 26, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	7	W1311..	4	Brownish to purplish clay	20·3	Plastic, very good	16	O.K........	7·2	02	0·4	10·4	Cream, very good	Hard
										2	0·6	9·9	Buff........	Fair
										6	1·0	8·8	Cream, very good	Hard
1	11	W1310..	7	Dark grey and brown, carbonaceous silt	26·6	Plastic, tough, greasy	26	Cracked badly	10·5	10	5·7	3·1	Dirty brown	Vitrified
										6	5·2	3·2	Dirty brown	Very hard
										2	4·9	3·5	Dirty brown	Hard
0	10	W1308..	Not classified	Grey, dark grey, mottled silt	29·0	Very plastic, good	15	Cracked badly	9·4	02	3·0	9·2	Salmon.....	Hard
										2	3·0	5·4	Salmon.....	Hard
										6	3·2	8·9	Salmon.....	Hard

TABLE 68

Locality: about southern part Sec. 11, Tp. 3, Range 25, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	W1443.. Selected	Not classified	Light grey clay...	24·6	Plastic............	28+	....	....	....	....	....	....	....

TABLE 69

Locality: about Sec. 17, Tp. 3, Range 25, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1511..	Not classified	Pale grey, yellowish green clay	....	....	2	....	....	....	....	....	....	....
0	9	W1510..	Not classified	Same, not weathered	....	....	4-	....	....	....	....	....	....	....
0	6	W1509..	Not classified	Mauve to light grey, carbonaceous clay	....	....	2+	....	....	....	....	....	....	....
0	3	....	Not tested....	Purplish clay.....	....	....	....	....	....	....	....	....	....	....
1	0	W1182..	1 or 2	Purplish, mauve clay	35·9	Very plastic......	33+	....	....	....	....	....	....	....
....	2½	....	....	Brown, carbonaceous clay	....	....	....	....	....	....	....	....	....	....
1	2	....	....	Lignite..........	....	....	....	....	....	....	....	....	....	....
1	7	W1508..	....	Brown, carbonaceous clay	....	....	20	....	....	....	....	....	....	....

TABLE 70

Locality: Sec. 13, Tp. 3, Range 24, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
3	0	W1442	5	Pale grey to white, silty clay	28	Very plastic, good	20+	O.K........	8·7	10	7·9	0·07	Dark grey, specks	Vitrified
										6	3·4	10·3	Light cream, fairly clean	Very hard
										2	5·5	6·6	Cream, somewhat stained, some fine specks	Hard
4	0	W1441	6	Light grey, silty clay	30·0	Very plastic, good	26	O.K........	10·5	10	7·5	1·3	Dark grey, specks	Vitrified
										6	6·2	5·6	Buff, dirty specks	Very hard
										2	4·8	8·4	Buff, dirty specks	Hard
4	7	W1440	9	Light grey to white, sandy clay	24·3	Fairly plastic.....	26	....	....	....	....	....	....	....
1	0	....	Not tested....	Ferruginous, sandy clay	....	....	....	....	....	....	....	....	....	....
3	5	W1439	Not classified	Hard, grey clay...	32·6	Plastic, good......	9	A small crack	9·5	06	1·5	18·4	Light salmon	Hard
										02	4·1	10·1	Salmon.....	Hard
										2	6·6	3·4	Salmon	Fair

TABLE 71

Locality: about NW. Sec. 7, Tp. 2, Range 22, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
				Yellow-weathering, very fine sand	....	....	....	....	....	....	....	....	....	....
3	0	W1117	Not classified	Bluish clay, yellow stained	27·2	Plastic, rather poor, slightly flabby	4+	Safe........	5·8	08	0	21·2	Light salmon	Soft
										06	0	21·1	Salmon.....	Fair
										04	0·7	21·0	Salmon.....	Hard
13	10	W1116	5	Silt..............	30·8	Plastic, very good	23	Safe........	8·2	04	3	11·28	Light buff..	Hard
										2	5·1	7·3	Fair buff....	Hard
										6	6·3	1·7	Dirty grey	Vitrified
0	10	W1118	5	Purplish silt......	24·6	Plastic, good......	19	O.K........	8·1	04	1·0	12·7	Light buff..	Hard
										2	2·6	8·6	Buff........	Hard
										6	4·7	4·88	Specks, buff	Very hard
2	0	W1119	4	Greyish buff clay	27·5	Plastic, very good	20	Safe........	8·0	04	1·2	14·3	Light buff..	Almost hard
										2	2·5	10·7	Fair buff....	Hard
										6	5·3	5·3	Buff, specks	Very hard
5	1	W1120	9	Pale grey, sandy clay	24·2	Fairly plastic, good	26	Safe........	7·0	04	0	16·1	Light buff..	Fair
										2	0·4	14·6	Buff........	Fair
										6	1·9	12·2	Dirty buff..	Hard
0	2	....	....	Brown, lignitic clay	....	....	....	....	....	....	....	....	....	....
1	7	W1121	7	Purplish brown, carbonaceous clay	36·6	Very plastic, tough, good	15	Cracked....	11·3	04	1·7	12·8	Brown-buff	Hard
										2	7·0	4·2	Poor brown	Hard
										6	8·0	0·2	Dark brown	Vitrified

Table 72

Locality: west side Big Muddy Valley, south of Big Muddy Lake, west of Keogh ranch house

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Greenish, yellowish silt	....	....	....	....	....	....	....	....	....	....
1	0	W1130	5	Greenish and white silt	29·2	Plastic, very good	20	Very slight tendency to crack	8·7	04	1·8	13·8	Light buff..	Fair
										2	3·7	10·5	Buff, specks	Hard
										6	6·0	5·2	Dirty buff..	Very hard
0	4	....	....	Yellowish green, fine silt	....	....	....	....	....	....	....	....	....	....
2	11	W1129	7	Light buff-grey, silty clay	33·3	Very plastic, very good	26	Seems safe .	8·2	04	4	8·8	Buff........	Hard
										2	7·7	0·9	Poor........	Hard
										6	7·2	0	Dirty grey	Vitrified
4	7	W1128	5	White silt........	23·8	Plastic, good......	20	O.K........	8·3	04	0·4	13·7	Light buff..	Fair
										2	1·0	12·8	Fair buff....	Hard
										6	2·6	9·2	Buff, specks	Hard
1	2	W1127	....	Yellow, concretionary band	....	....	....	....	....	....	....	....	....	....
2	0	W1126	7	Purplish grey clay	31·2	Very plastic, good	16	Cracked slightly	8·5	04	2·8	9·7	Dark buff..	Fair
										2	6·8	0·13	Poor brown	Hard
										6	7·7	0	Grey.......	Vitrified
1	3	W1125	7	Purplish grey clay	25	Plastic, very good	16+	Slight tendency to crack	7·7	04	0·5	13·7	Light buff..	Fair
										2	2·9	9·3	Fair buff....	Hard
										6	4·2	2·3	Fair buff....	Vitrified
3	7	W1124	Not classified	Grey, silty clay...	24·6	Plastic, good......	16	Cracked badly	8·1	04	0·8	11·4	Dark buff..	Hard
										2	3·1	6·5	Salmon.....	Hard
										6	5·0	3·4	Dirty buff..	Almost vitrified
5	7	W1123	Not classified	Greenish grey silt	25	Plastic, good......	14	Cracked....	8·3	04	0·5	11·0	Salmon.....	Fair
										2	3·1	6·4	Good red...	Hard
										6	4·8	2·3	Dark brown-red	Vitrified

TABLE 73

Locality: on east side Big Muddy Valley, south of Big Muddy Lake, in NE. Sec. 1, Tp. 2, Range 22, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	Not tested....	Yellow, silty clay.	....	....	....	....	....	....	....	....	....	....
1	7	W1103	Not classified	Light green clay (very calcareous)	31	Quite plastic, good	2½	Satisfactory	6·5	5	....	....	Salmon.....	Hard
3	2	W1102	Not classified	Light green, silty clay	28	Quite plastic, good	9	Satisfactory	6·6	5	....	....	Salmon.....	Hard
6	3	W1101	1 indicated..	Dark purplish grey clay	36	Quite plastic, very tough	32+	Cracks badly	8·6	5	....	....	Almost white	Hard
9	0	W1100	....	Pale purplish grey, sandy clay	....	....	....	....	....	....	....	....	....	....
2	8	....	....	Light purplish grey, sandy clay	....	....	....	....	....	....	....	....	....	....
10	4	....	....	Light purplish grey, sandy clay	....	....	....	....	....	....	....	....	....	....
		W1099	Not classified	Top 4 feet.........	....	Rather short......	20+	Satisfactory	....	....	....	....	....	....

TABLE 74

Locality: NW. Sec. 18, Tp. 4, Range 2, W. 3rd Mer., on west slope of a high hill

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Yellow siltstone, etc.	....	....	....	....	....	....	....	....	....	....
3	7	C753	6 indicated...	Dark grey clay, concretions	38	Quite plastic, somewhat tough	20+	Cracks slightly	10·2	5	....	....	Poor brown	Hard
2	0	C754	4 indicated...	Dark purplish clay	29	Quite plastic, very good	27	Satisfactory	7·3	5	....	....	Clean, light buff	Hard
1	0	....	....	Purplish, silty clay	....	....	....	....	....	....	....	....	....	....
1	4	C755	6 indicated...	Pale green clay...	37	Quite plastic, very good	26+	Satisfactory	9·1	5	....	....	Buff to brown	Hard
1	6	W941	4 indicated...	White, silty clay..	27	Quite plastic, good	26	Satisfactory	7·1	5	....	....	Light buff..	Hard
0	6	....	....	Yellow-stained, silty clay	....	....	....	....	....	....	....	....	....	....

TABLE 75

Locality: NE. Sec. 13, Tp. 4, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
6	0	C762	1 or 2 indicated	Dark purplish, somewhat sandy clay	23	Quite plastic, good	28	Satisfactory	6·4	5	....	....	Almost white	....
3	8	C761	4 indicated...	Pale greenish cream clay	31·2	Plastic, very good	23	Satisfactory	9·0	04 2 6	2·0 3·3 5·2	12·0 10·0 5·6	Clean cream Clean cream Clean buff..	Hard Hard Very hard
1	0	C760	4 indicated...	Light green, fine silt	28·3	Plastic, very good	19	Slight tendency to crack	8·4	04 2 6	1·2 2·4 4·0	14·6 10·3 7·2	Clean cream Clean cream Clean buff..	Fair Hard Very hard
4	2	C759	4 indicated...	Green and purplish clay	25	Plastic, very good	18	Safe........	8·0	04 2 6	0·8 2·2 4·3	12·1 9·7 5·1	Clean cream Clean buff.. Clean buff..	Fair Hard Very hard

TABLE 76

Locality: in Sec. 23, Tp. 4, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	2	....	Not tested...	Yellow clay, concretions	....	....	....	....	....	....	....	....	....	....
1	6	C654	Not classified	Whitish clay......	....	....	15½	....	....	....	....	....	....	....
6	0	....	Not tested...	Whitish silt......	....	....	....	....	....	....	....	....	....	....
....	....	C655	Not classified	From top 1 foot...	....	....	18	....	....	....	....	....	....	....

Table 77

Locality: south of Lugenville Siding, in approximately Sec. 36, Tp. 2, Range 3, W. 3rd Mer.

Thickness Ft	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	6	....	....	Grey clay........	....	....	....	....	....	....	....	....	....	....
		W1691	7	Sample from middle	39	Very plastic, good, somewhat tough and greasy	29	Cracked....	11·5	2	7·6	0·5	Poor, grey, stained	Hard
										6	8·5	0·4	Stained white	Very hard
										10	8·5	0·1	Dirty grey.	Very hard
3	0+	....	....	Pale green, silty clay	....	....	....	....	....	....	....	....	....	....
2	6±	....	....	Brownish grey, carbonaceous clay	....	....	....	....	....	....	....	....	....	....
		W1692	7	Sample from middle	33·5	Very plastic, very good	18	Cracked slightly	9·1	04	3·1	9·8	Good light buff	Hard
										2	4·8	7·1	Good buff, clean	Hard
										6	6·3	0	Clean, grey	Vitrified

Table 78

Locality: near boundary between Sec. 36, Tp. 2, Range 3, W. 3rd Mer., and Sec. 31, Tp. 2, Range 2, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Light green, carbonaceous, mottled, silty clay	....	....	....	....	....	....	....	....	....	....
		W1693	4	Sample from middle	26·6	Plastic, very good	23	Cracked very slightly	8·3	04	0·6	13·32	Good light buff	Hard
										2	3·0	7·8	Fair buff, clean	Hard
										6	3·7	7·0	Clean buff..	Very hard

TABLE 79

Locality: SW. Sec. 13, Tp. 2, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0±	....	....	Purplish, mottled clay	....	....	....	....	....	....	....	....	....	....
2	6±	....	....	Greenish grey clay	....	....	....	....	....	....	....	....	....	....
2	0±	....	....	Whitish, silty clay	....	....	....	....	....	....	....	....	....	....
		W1696	4 indicated...	Sample from middle	25·6	Slightly plastic, fairly good	29+	O.K.......	6·3	3	1·1	14·0	Light cream	Hard

TABLE 80

Locality: Sec. 34, Tp. 2, Range 3, W. 3rd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
....	....	....	....	Yellowish silt....	....	....	....	....	....	....	....	....	....	....
....	....	W1695	7 indicated...	Grey-green clay...	28·6	Plastic, very good	16	Cracked badly	9·4	04 2 6	1·7 4·5 6·3	9·9 4·9 2·7	Fair buff... Fair buff... Dark grey..	Hard Hard Vitrified

TABLE 81

Locality: about centre Sec. 11, Tp. 3, Range 30, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	2	W1425	Not classified	Brownish grey silt	24·0	Very short.......	30+	....	....	....	....	....	....	....
0	2	....	Not tested...	White silt........	....	....	....	....	....	....	....	....	....	....
2	5	W1424	6	Light brown clay, and silt	25·0	Plastic, good.....	23	O.K.......	9·5	10	0·7	9·9	Buff, iron-stained	Hard
										6	0·6	10·8	Buff, fairly clean	Hard
										2	0·6	10·7	Buff, stained	Hard
2	5	W1423	6	Light brownish grey clay, sandy clay	21·5	Plastic, good.....	20	O.K.......	8·2	10	1·2	8·0	Buff, iron-stained	Hard
										6	1·0	10·3	Dirty buff..	Hard
										2	0·7	11·0	Buff, stained	Hard
3	6	W1422	6	Pale green, silty clay	27·5	Plastic, very good	23	O.K.......	7·7	10	4·3	7·6	Buff, iron-stained	Hard
										6	1·9	12·0	Dirty buff..	Hard
										2	1·7	12·8	Buff, stained	Hard

Table 82

Locality: about Sec. 11, Tp. 3, Range 30, W. 2nd Mer., west of preceding locality

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	5	W1421	Not classified	Brown clay	43·0	Very plastic, sticky	11	Cracks	....	....	....	....	....	....
0	2	....	....	Green shale	....	....	....	....	....	....	....	....	....	....
0	5	....	....	Yellow, concretionary sandstone	....	....	....	....	....	....	....	....	....	....
0	6	W1420	7	Grey clay	32·5	Very plastic, good	15	O.K.	9·0	02 2 6	5·4 6·4 7·2	6·6 4·0 1·5	Fair buff Dirty brown Dirty brown	Hard Very hard Very hard
2	8	W1419	5	Light grey, almost white, clay	29·0	Very plastic, good	15	O.K.	8·7	02 6 2	3·8 5·7 4·3	9·8 5·6 6·5	Cream Buff Buff	Hard Very hard Hard

Table 83

Locality: SW. Sec. 11, Tp. 3, Range 30, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1434	6	Purplish brown clay	29·0	Plastic, tough, stiff	29	O.K.	9·7	10 6 2	5·1 7·5 6·3	1·9 5·5 7·1	Grey Dirty cream Dirty cream	Vitrified Very hard Hard
2	0	W1433	Not classified	Grey and brownish clay	26·0	Plastic	15	....	....	....	....	....	....	....

TABLE 84

Locality: about SW. Sec. 33, Tp. 2, Range 30, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	2	W1382	Not classified	Dolomitic, grey, irregularly banded clay	34·6	Very plastic, very good	3	Cracked slightly	10·0	08 06 02	1·6 1·7 8·6	17·3 16·7 0·64	Pink-buff... Light salmon Poor brownish	Hard Fair Hard
0	½	....	....	Lignitic layer.....	....	....	....	....	....	....	....	....	....	....
0	4	W1381	1	Brownish clay....	29·3	Plastic, very good	32	Cracked slightly	8·8	10 6 2	9·3 5·9 2·4	3·6 10·5 15·2	Pure white, clean Pure white, clean Pure white, clean	Very hard Very hard Hard
0	½	....	....	Lignitic layer.....	....	....	....	....	....	....	....	....	....	....
0	7	W1380	1	Brown clay.......	29·6	Plastic, good.....	30	O.K........	9·1	10 6 2	8·8 6·9 4·0	0·35 5·8 12·1	Very light grey White, clean Pure white, clean	Vitrified Very hard Hard
1	2	W1379	4	Mottled brown and grey clay	27·3	Plastic, very good	20	Cracked very slightly	9·8	10 6 2	4·9 2·9 1·7	2·9 7·5 10·3	Grey....... Cream, clean Cream, clean	Vitrified Very hard Hard

TABLE 85

Locality: southern part of Sec. 26, Tp. 2, Range 30, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	1	W1416	Not classified	Dark grey clay...	42·6	Very plastic, tough, sticky	28	....	....	....	....	....	....	....
1	5	W1415	Not classified	Mixed, dark grey clay and fine sand	19·0	Slightly plastic...	23	....	....	....	....	....	....	....
1	0[1]	W1414	9	Dark grey, sandy clay	24·0	Plastic..........	23	....	....	....	....	....	....	....
1	0[1]	W1413	9	Dirty, light grey, sandy clay	23·3	Slightly plastic...	23	....	....	....	....	....	....	....
1	5[1]	W1412	Not classified	Whitish, sandy clay	24·0	Slightly plastic...	23	....	....	....	....	....	....	....
2	0	W1411	7	Pale green clay...	27·0 31·0	Very plastic, good	14	Cracked very slightly	8·7	02 2 6	5·8 7·0 7·0	4·8 0·6 0·8	Brown-buff Dirty brown Dirty brown	Hard Hard Very hard

[1] Approximate.

TABLE 86

Locality: SW. Sec. 29, Tp. 2, Range 29, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
2	0	W1409..	Not classified	Dark grey to chocolate clay	26·6	Plastic, good......	15	Cracked slightly	9·0	02	2·4	9·3	Poor buff...	Hard
										2	2·3	7·4	Grey-buff, poor	Hard
										6	3·1	6·2	Greenish buff, poor	Very hard
1	10	W1408..	4 indicated...	Pale greenish grey clay	28·0	Plastic, very good	17	O.K........	8·4	10	5·8	1·4	Dark grey..	Vitrified
										6	3·6	7·4	Cream, clean	Very hard
										2	2·1	9·3	Light cream, clean	Hard
3	0	W1407 .	6 indicated.	Pale green to white clay	29·0	Plastic, very good	15	O.K........	9·7	02	4·0	6·0	Buff........	Hard
										2	4·1	5·4	Brown-buff	Hard
										6	4·7	4·4	Brown-buff	Very hard

TABLE 87

Locality: 10 feet below horizon of preceding table, at same locality

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
0	2	W1405..	Not classified	Whitish, silty clay	20·0	Plastic........	13	....	....	....	....	....	....	....
0	7	W1404..	Not classified	Mottled, dark grey and whitish clay	27·3	Plastic...........	15	O.K........	10·0	02	2·4	8·9	Buff........	Hard
										2	3·6	5·8	Brown-yellow	Hard
										6	2·6	6·1	Brownish yellow	Very hard
2	0	W1403..	Not classified	Mottled, dark grey, silty clay	30·0	Very plastic, good	14	Cracked....	10·0	02	2·1	9·0	Green-cream	Hard
										6	3·3	8·8	Yellow-brown	Very hard
										2	3·3	6·1	Green-cream	Hard
1	0	....	....	Fine, yellowish grey silt	....	....	....	....	....	....	....	....	....	....
1	0	W1402..	Not classified	Yellowish green, sandy clay	22·2	Very short........	14	....	....	....	....	....	....	....

TABLE 88

Locality: 25 feet below horizon of preceding table, at same locality

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
4	4	W1399..	Not classified	Dark grey, calcareous clay	37·6	Very plastic......	9	....	....	....	....	....	....	....
1	1	W1397..	Not classified	Greenish grey clay	34·0	Very plastic......	14	....	....	....	....	....	....	....
1	0	W1398..	Not classified	Grey clay........	34·4	Plastic...........	3	....	....	....	....	....	....	....

TABLE 89

Locality: 100 feet below horizon of preceding table and at same locality

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1410..	Not classified	Dark brown, carbonaceous clay	27·3	Plastic, good.....	14	Cracked slightly	9·7	02	2·6	8·5	Buff........	Hard
										2	3·4	6·0	Brown-buff	Hard
										6	3·3	5·7	Brown-buff	Very hard

TABLE 90

Locality: Sec. 2, Tp. 1, Range 24, W. 2nd Mer.

Thickness Ft.	Thickness Ins.	Field No.	Type No.	Colour, grade	Tempering water %	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness
1	0	W1145.. Selected	Not classified	White, silty clay..	26·1	Plastic...........	18	....	....	....	....	....	....	....

APPENDIX II: PETROGRAPHY OF THE WHITEMUD AND WILLOWBUNCH CLAY SAMPLES

By F. J. Fraser

The following description of the clay samples includes sandy samples that contain enough clay to make sufficiently plastic to justify their examination from an economic standpoint.

The samples fall into four natural groups:

(1) Grey and white sands with a high clay content
(2) White silts and clays
(3) Dark sandy clays
(4) Dark clays with little or no sand

The grey sands contain as essential constituents quartz, feldspar, chert, kaolin, a white micaceous mineral, and clay. Accessory constituents are iron carbonates, occasional carbonaceous fragments, and the heavier accessory minerals, zircon, tourmaline, and rutile; anatase may be present, and garnet occurs in the coarser grades of sand. Other minerals include epidote and andalusite, but are not of sufficient importance to justify more than the mention of their occurrence. The coarser grades may also include flakes of a fresh black mica.

The quartz is angular and subangular; occasional rounded grains may be found, but in no greater proportion than is to be expected from samples collected over such a wide area.

The feldspar grains are badly decomposed and very cloudy, often to the complete elimination of interference colours under crossed nicols. Clear grains showing albite twinning, and fresh microcline are persistent in some of the samples. Some of the clear feldspar grains are beautifully zoned, show definite traces of crystal form, and are most certainly authigenous; they could never have survived the mechanical and chemical agencies that have broken down the feldspar grains with which they are associated. Rounding of crystal edges on the secondary grains is referred to incipient re-solution.

The chert grains are dark and worn, and show the dull polish this mineral acquires during transportation. Frequently some of these grains show clear, siliceous veinlets.

The kaolin in the coarser grades occurs in thick, white or cream-coloured, highly lustrous, platy grains, built up of fine laminæ, and shows a pseudo-columnar habit and curvature along the length. In the finer grades the mineral occurs as thin plates, often with a rectangular habit; these thin laminæ are translucent, becoming cloudy and opaque as the thickness increases. In the darker clay samples the kaolin is brownish. The white, micaceous mineral whose appearance suggests sericitic mica may be in part, or wholly, kaolin or another clay mineral.

The grey sands owe their colour to the mixture of quartz and feldspar, and to the chert grains; the darker colour of some of the samples is due to iron staining. When the clay is washed out of these samples, the residue is a pepper and salt grey owing to the removal of the powdery clay coating from the chert grains. In W33 biotite flakes help to darken the tint, and in W906 the tint is influenced by pink and light brown, sharply angular grains; in W1275 the dark grains are in part lignite; in W1446, a grey sand, the colour is due to a mixture of quartz, feldspar, and chert grains only. A few grey samples, which are so light in colour as to approach a cream or nearly white, are almost or entirely free from dark grains; for example, W54 after washing shows so few dark grains that they do not influence the colour of the sand grade. W510 and W1377 contain much large white feldspar and considerable iron carbonate aggregates which are of varying shades of light brown, although the colour and larger size of the latter do not influence the colour either of the original sample, or of the sand grade after washing.

The white silts and clays only differ in appearance in the hand specimen from the grey sands in their colour and texture according as they are more compact or powdery. Examples are: W37, containing 9·4 per cent of clean, sharp sand with few dark grains; W85, containing 21·4 per cent of similar sand; W87 and W509 contain no sand, but a low content of small iron spherules; W1656 contains 1 per cent of sand which is high in quartz, and some iron aggregates. The freedom of the lighter coloured samples from dark grains suggests that any such have suffered solution in the original sediment during the decomposition of the feldspars. The white silts and clays contain abundant, white, micaceous flakes whose size is proportional to the grade of the sample. The whiteness of some of the clay samples may have been caused by the bleaching action of the carbonaceous fragments.

The dark clays and sandy clays vary in colour from dark brown to grey. Those containing lignite fragments contain no sand and only a little, clean, superfine sand or coarse silt. The colour of the original sample is no guide to the carbonaceous content; for instance, W1327 and W1390, W1389 and W1461 contain lignite fragments, but the first two are much lighter in colour than the last two. W659 is an example of a dark clay with 16·2 per cent sand. Examples of light-coloured dark clays with little or no sand are W1269 and W1403; W659 and W1054 are similar, but darker in colour. Intermediate between the white silts and clays, and the dark silts and clays are all gradations of colour.

Of particular interest in W1734, the sand grade of which is almost entirely composed of kaolin. The colour of the sample is brownish grey with no indication of its mineral composition until the fine clay is washed away, when the thick, platy, and curved columnar kaolin is easily recognized under a low magnification.

The Willowbunch samples are similar to those of the Whitemud and appear to have suffered much the same type of decomposition. The white, flaky, micaceous mineral is common, the coarser sand grades contain chert grains, as in W1063. The clay content is high, and the quartz content is higher in the finer sand grades than in the coarser sand grades. All the Willowbunch samples are light in colour, and iron is present only in the form of spherules or aggregates as in the Whitemud samples. The heavy accessory minerals are restricted to zircon, tourmaline, and rutile.

PALÆOZOIC AND JURASSIC FORMATIONS IN WELL SECTIONS IN MANITOBA

By R. T. D. Wickenden

CONTENTS

INTRODUCTION

To those engaged in drilling for oil and gas, a knowledge of the successions of formations is invaluable. In a drift-covered country underlain by nearly horizontal strata, such as Manitoba, deep wells furnish the only means of studying the sedimentary section for any one locality. The results of a study of the records furnished by deep wells in Manitoba are presented here. Unfortunately, many details cannot be supplied by such a study, and it is only by applying the knowledge gained from surface studies to the information gained from wells that we are able to visualize the whole section. The writer is cognizant of the limited nature of the information obtainable from his study, but at least it is possible to define horizons that are recognizable when drilling, which is not always true of horizons defined from the study of outcrops only.

Jurassic formations are considered by many geologists to be the source of some of the oil and gas found in the western part of the prairies and in the foothills of the Rocky Mountains. The distribution of these beds, therefore, is of interest to those searching for oil or gas fields. In Manitoba Jurassic beds are not exposed at the surface, but studies of samples from deep wells indicate that Jurassic strata occurring in southern Alberta and northern Montana apparently extend across southern Saskatchewan into southern Manitoba. Near the shore-lines of the sea in which the Jurassic beds were deposited one may expect to find sands that may serve as reservoir beds for oil or gas provided the structure is suitable.

In southern Manitoba between the basal beds of the Upper Cretaceous and the top of the Palæozoic there is a series of beds that has not been recognized in outcrops and has been almost unnoticed in wells. Dowling[1] designated as Jurassic what appears to be the same series in the Neepawa well in Manitoba. Recent drilling at two localities in Manitoba has yielded a fair series of samples from these beds, and these show that the upper part is probably Lower Cretaceous and the lower part is definitely Jurassic. The Jurassic consists of what appear to be three members or possibly formations. The uppermost is a grey, marine shale, the middle is a varie-

[1] Dowling, D. B., Slipper, S. E., and McLearn, F. H.: Geol. Surv., Canada, Mem. 116, p. 37 (1919).

gated, non-marine shale, and the lowest is a grey and white, marine shale. Samples from the Commonwealth Manitou No. 2 well afford the most complete series from these beds, but samples from the Dauphin Oil and Gas Syndicate well on Vermilion River also afford information regarding the Jurassic beds.

The Palæozoic formations of Manitoba are confined to the Ordovician, Silurian, and Devonian periods. The Ordovician rocks have been divided into three formations or series named, in ascending order, the Winnipeg, Red River, and Stony Mountain. The Winnipeg formation consists of sand and shale and rests directly on the Precambrian. The Red River division is made up of dolomite and limestones, and consists of three members: the Dog Head (Lower Mottled), Cat Head, and Selkirk (Upper Mottled). The Stony Mountain limestone is the uppermost division of the Ordovician. All three are considered to be of Richmond age. The Silurian is represented by only one formation, the Stonewall. The formations of Devonian age are, in ascending order, the Elm Point, Winnipegosan, and Manitoban. The Elm Point is of Middle Devonian, and the others are of Middle or Upper Devonian age.

These Palæozoic formations have been defined from a study of the surface exposures. Because the formations are almost flat-lying and the surface is practically level, and because many parts of the formations have not been seen at the surface, considerable doubt exists as to the composition and limits of the various formations. In no one locality have all the formations of any one period been observed.

The results obtained by the study of the deep well records are expressible in columnar sections for three different localities. The section for the southernmost locality is based on a well drilled by the Commonwealth Oil and Gas Company near Manitou. A second section is for a locality about 150 miles north and a little west, in the vicinity of Dauphin and Lake Winnipegosis. No one well in this vicinity was bored completely through the Palæozoic section which, therefore, has been constructed by interpolating information derived from three wells, the Dauphin, Ochre River, and Winnipegosis wells. The third and northernmost section is for a locality about 120 miles farther north, in the vicinity of Mafeking, where a diamond-drilled well and several standard rig wells have yielded samples from all the Palæozoic beds in the vicinity. Each sample from these wells was examined lithologically and a portion of each was disintegrated and examined for micro-fossils. The age determination of the strata assigned to the Jurassic is based on the occurrence of fragments of belemnites, as well as on the presence of some of the same species of foraminfera and ostracoda that were found in the Jurassic beds in Saskatchewan and Alberta.

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WELL LOGS

MANITOU NO. 2 WELL

Drilled by Commonwealth Oil and Gas Company

Location: L.S. 8, Sec. 26, Tp. 2, Range 9, W. 1st Mer.

The samples from 0-735 feet are from glacial drift and the underlying Upper Cretaceous strata down to the basal beds.

			Depth Feet
Lower Cretaceous		Shale, medium grey	738–755
		Shale, light grey	755–764
		Shale, light grey and reddish brown	764–780
		Shale, light grey	780–820
		Shale, medium grey	820–853
		Shale, reddish brown and grey	855–860
		Shale, medium grey	860–870
		Shale, reddish brown	870–880
		Shale, medium grey	880–890
		Shale, reddish brown and grey	890–895
		Sand, light grey to white; fine grains; quartz	895–900
Jurassic		Shale, medium grey, containing marine fossils	900–970
		Shale, variegated, reddish brown, green, white, and yellow; somewhat calcareous; contains chara fruit, smooth ostracods, and waterworn shell fragments; some gypsum at 1,040 feet; non-marine	970–1,060
		Shale, medium grey; marine fossils	1,060–1,070
		Shale, medium grey and reddish brown; marine fossils	1,070–1,090
		Shale, calcareous, sandy, light grey and white	1,090–1,110
Devonian		Dolomite, light buff and grey	1,110–1,140
		Shale, light grey, some sand at 1,150–1,160 feet	1,140–1,200
		Missing	1,200–1,210
		Shale, cream coloured	1,210–1,220
		Shale, reddish brown, grey, and white; much gypsum	1,220–1,270
		Shale, grey and reddish brown	1,270–1,280
		Shale, reddish brown	1,280–1,300
		Missing	1,300–1,340
		Shale, reddish brown; much gypsum	1,340–1,390
		Sand, quartz, reddish stain, medium to coarse grains, well rounded	1,290–1,400
		Shale, reddish brown	1,400–1,430
		Limestone, dirty cream	1,430–1,450
		Dolomite, mauve to pink	1,450–1,470
		Shale, brick-red	1,470–1,490
?		Dolomite, pink	1,490–1,500
		Limestone, pink	1,500–1,510
		Limestone, light grey	1,510–1,530
		Dolomite, pink	1,530–1,540
		Dolomite, cream coloured	1,540–1,550
		Dolomite, pink	1,550–1,570
		Limestone, cream coloured	1,570–1,580

			Depth Feet
Silurian (?).......		Dolomite, pink..........................	1,580–1,600
		Limestone, cream coloured................	1,600–1,620
		Dolomite, pink..........................	1,620–1,705
		Dolomite, cream coloured................	1,705–1,790
		Shale, brick-red; sand, quartz............	1,790–1,800
		Dolomite, pink..........................	1,800–1,850
		Dolomite, brown and grey................	1,850–1,870
		Sandy dolomite, grey.....................	1,870–1,890
		Dolomitic sandstone......................	1,890–1,900
	Stony Mountain..	Sandy dolomite and calcareous shale......	1,900–1,910
		Limestone, medium grey..................	1,925–1,933
		Sand, light grey.........................	1,935
		Missing.................................	1,935–1,940
		Dolomite, light grey......................	1,940–1,980
		Dolomite, medium grey..................	1,980–2,000
		Dolomite, buff and grey..................	2,000–2,017
Ordovician........	Red River........	Dolomite, cream..........................	2,030
		Dolomite, medium grey..................	2,040
		Dolomite, buff and grey..................	2,045
		Dolomite, light buff......................	2,055
		Dolomite, cream coloured................	2,060–2,080
		Limestone, cream coloured................	2,080–2,130
		Limestone, cream coloured................	2,145–2,290
		Dolomite, cream coloured................	2,290–2,340
		Calcareous mud..........................	2,350
		Limestone, cream coloured................	2,360
		Calcareous mud..........................	2,370
		Dolomitic mud...........................	2,380
		Calcareous mud..........................	2,390
		Limestone, cream coloured................	2,400
		Dolomitic mud...........................	2,410–2,430
		Calcareous mud..........................	2,440
		Dolomitic mud...........................	2,450
		Calcareous mud..........................	2,460–2,480
	Winnipeg..........	Shale, dull green.........................	2,490–2,600
		Sand, medium grained, quartz............	2,600–2,602
		"Arkose", green-grey.....................	2,610–2,612
		Shale, dull green.........................	2,612–2,613
Precambrian......		"Granite", brown stained, much decomposed, much biotite.....................	2,615–2,639

Some of the beds placed in the Lower Cretaceous are probably marine because, at 830 feet, a pelecypod was found that resembles the genera *Camptonectes* or *Lima*. If the specimen belongs to one of these genera, or a related genus, it is probably of marine origin. The reason for assigning to the Lower Cretaceous the beds from 738 to 900 feet is that they lie above beds determined to be Jurassic and below other beds considered to be Upper Cretaceous. Dr. S. R. Kirk has stated personally that he has found plant evidence of the presence of Lower Cretaceous strata in Manitoba.

Directly below the sand bed, at 895-900 feet, are shales that contain Jurassic marine micro-fossils including *Marginulina* cf. *lacunata* (Terquem) and *Lenticulina* cf. *limata* (Schwager). They also hold two species of ostracods that are the same as species found in Jurrasic beds in Saskatchewan, and numerous fragments of echinoderms, brachiopods, and belemnites. The variegated beds between 970 and 1,060 feet contain numerous specimens of chara fruit and smooth ostracods. The latter resemble the genus *Paracypris*. These fossils indicate that the variegated beds are probably non-marine. The beds are somewhat calcareous, but this may be due to the numerous shell fragments, which, probably, were derived from the underlying marine beds. All the shell fragments have rounded edges and many are somewhat polished.

The contact between the variegated beds and the underlying marine member is probably represented in the sample from 1,050-1,060 feet, since it seems to contain about an equal amount of material typical of both the variegated and marine beds.

The marine beds that make up the basal division are somewhat like the upper marine horizon of the Jurassic. The best marine fossils were found in the samples from 1,080-1,090 feet. They include species of *Guttulina* and also other foraminifera and fragments of fossils such as were found in the higher marine division. The beds from 1,090-1,110 feet contain very few marine fossil fragments and there are many rock fragments of medium to fine-grained sand embedded in a calcareous matrix. It is evident that these deposits are the basal beds derived from the underlying Palæozoic strata.

The contact between the Devonian and the Jurassic is placed at 1,110 feet because of the change in lithology from soft shales and sand to dolomite. The first fossils found below this contact are fragments of brachiopods and some ostracoda at 1,430-1,440 feet. The ostracoda are exactly the same as some found in the upper samples of the Winnipegosis well. The great thickness of red shale and dolomite between 1,120 and 1,430 feet possibly represents the beds in the upper part of the Palæozoic of the Dauphin well (330-495 feet). The succession, below the red shale, of cream-coloured limestone followed by mauve to pink dolomite, has exactly the same colour change as that found below the red shale in the Dauphin well (500-550 feet), though in the Dauphin well there is dolomite in place of the limestone. The succession in the two wells is so much alike that, lacking evidence to the contrary, the strata between 1,430 and 1,470 feet in the Manitou No. 2 well are correlated with those between 500 and 550 feet in the Dauphin well.

In the case of the Manitou No. 2 well the base of the Devonian has been tentatively drawn at 1,490 feet. In the log of this well published in Summary Report 1932, Part B, it was placed at the base of the red shale (1,400-1,430 feet), but as already stated the strata between 1,430 and 1,470 feet so closely resemble strata confidently believed to be Devonian in the Dauphin well that it is clearly evident the contact is still lower. It has been placed at the base of the red shale, at 1,490 feet, because this seems to mark a boundary between a shale and dolomite group above and a limestone and dolomite group below. There is a possibility, however, that this contact may be still lower. No fossils could be found in any of the beds tentatively assigned to the Silurian. The compactness of the dolomite and its pink colour are features resembling those possessed by what appear to be Silurian rocks in the Winnipegosis well.

If the base of the Devonian is placed at 1,490 feet, the assumption has to be made that the lower part of the Devonian rocks found in the

Winnipegosis and Dauphin wells is missing in the Manitou area. If so a considerable disconformity exists between the Devonian and Silurian in this area.

The strata between 1,900 and 1,910 feet belong to the Ordovician because micro-fossils of the same species as those found in the Stony Mountain formation were found in a calcareous bed at 1,910 feet below a sandstone. These fossils belong to species from the Stony Mountain formation identified by Ulrich.[1] Among the most easily recognized species are *Sceptropora facula* Ulrich, *Batostoma manitobense* Ulrich, and *Primitia parallela* Ulrich. These fossils are also common in the sample representing 30-115 feet in the Stony Mountain well.

The division between the Stony Mountain and Red River formations is based on a change of colour. The thickness of the beds thus assigned to the Stony Mountain also agrees very closely with the estimated thickness.

The separation of the various horizons in the Red River formation was not attempted because of lack of reliable data.

The separation of the Winnipeg from the Red River formation is based on lithological grounds.

DAUPHIN WELL

Drilled by the Dauphin Oil and Gas Syndicate

Location: SE. ¼ Sec. 14, Tp. 24, Range 20, W. 1st Mer.

The samples from 0-130 feet represent the Assiniboine, Keld, and Ashville beds.

		Depth Feet
	Basal beds and Lower Cretaceous? Shale, medium grey, sandy	130–160
Jurassic	Shale, light grey, slightly sandy	160–170
	Shale, light grey, somewhat calcareous, with worn shell fragments, smooth ostracods, and chara fruit	170–200
	Shale, reddish brown and light grey; sandy	200–210
	Shale, light grey, some red	210–220
	Shale, light grey	220–230
	Shale, red	230–240
	Shale, light to medium grey	240–270
	Shale, these samples are mixed with much material from the Keld or Assiniboine beds, probably from the surface, for some fragments show weathering	270–310
	Shale, medium grey, glauconite, and numerous shell fragments	310–330
	Dolomite, light grey to white, much anhydrite	330–380
	Dolomite, buff to brown, with chert, gypsum, and anhydrite.	380–390
	Shale, reddish brown, with much gypsum	390–495
	Dolomite, dirty cream	495–510
	Dolomite, mauve to pink	510-520
	Missing	520–530
	Dolomite, mauve to pink	530–550
	Dolomite, dirty cream or buff	550–590
	Dolomite, mauve to pink	590–610
	Dolomite, light buff and white	610–650
	Dolomite, grey	650–670
	Dolomite, light buff	670–680

[1] Ulrich E. O.: "Contributions to the Micro-Palæontology of the Cambro-Silurian Rocks of Canada, Part II"; Geol. Surv., Canada, 1889.

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		Depth Feet
Devonian	Missing	680-690
	Dolomite, grey	690-710
	Dolomite, light grey	710-720
	Missing	720-730
	Dolomite. light grey, some gypsum	730-740
	Dolomite, buff	740-790
	Dolomite, pink	790-800
	Dolomite, pink, and limestone, white	800-820
	Dolomite, light buff	820-920
	Dolomite, brown	920-940
	Dolomite, and limestone, grey	940-990
	Limestone, medium grey	990-1,010
	Dolomite, buff and grey	1,010-1,050
Silurian	Missing	1,050-1,060
	Dolomite, reddish brown	1,060-1,070
	Missing	1,070-1,090
	Dolomite, grey and reddish brown; gypsum	1,090-1,110
	Anhydrite and gypsum, some dolomite	1,110-1,120
	Dolomite, buff, with much gypsum and anhydrite	1,120-1,130
	Dolomite, buff	1,130-1,170
	Dolomite (?), sample full of rust	1,170-1,180
	Dolomite, light buff or cream	1,180-1,230
	Shale, reddish brown	1,230-1,256

The uppermost Jurassic in this section appears to be a correlative of the non-marine beds in the Manitou well. The sediments and micro-fossils are exactly the same in both cases. The lowest 20 feet (310-330 feet) in the Dauphin well probably represent the lower marine horizon found in the Manitou well; a conclusion based chiefly on the occurrence of glauconite. The samples from this horizon do not show contamination as do those above. Fragments of a gastropod shell are present but no complete specimens, for the shells are rather fragile and have been somewhat crushed and distorted in the shale.

The contact between the Jurassic and the Devonian in this well is based on the occurrence of dolomite and chert as in the Manitou No. 2. The highest fossil horizon is at 650-670 feet where only unidentifiable fragments of brachiopods were found. The best fossil horizon occurs in the beds represented by samples from 940-990 feet. Some ostracods and fragments, both brachiopods and bryozoa, were found here. Among the ostracods a peculiar species of *Octonaria* is quite common in the samples from 960-975 feet. It is very probable that it is a good guide fossil for this horizon. A piece of core from about the same horizon in the Holmes well on Ochre River contains a fragment of a large *Atrypa* which is very probably Devonian. A little of the sample was crushed and examined for ostracods and other micro-fossils. A few ostracods were found in a sample from about 15 feet above the one that contained the brachiopods. The ostracod horizon is probably lower than that in which the *Octonaria* fauna was found in the Dauphin well. There is an unrepresented gap of 30 feet in the Ochre River well just where the *Octonaria* fauna would be expected to occur. It is evident from the similarity of the lithological succession in the two wells that the *Atrypa* found in the Ochre River well comes from the horizon represented by the dolomites between 975 and 1,000 feet in the

Dauphin well. The limestone represented by the samples between 990 and 1,010 feet in the Dauphin well may be the Elmpoint limestone. It is by no means a pure limestone, for a gravity analysis showed about 40 per cent dolomite and a little over 50 per cent calcite.

The contact between the Silurian and Devonian is placed at 1,060 feet, chiefly because this seems to be the horizon at which occurs the most marked change in lithology between the horizons bearing Devonian fossils and what is probably the Silurian gypsum and anhydrite beds at 1,090-1,130 feet. No fossils were found in the samples from the so-called Silurian.

WINNIPEGOSIS WELL

Location: Sec. 29, Tp. 30, Range 17, W. 1st Mer.

—	—	—	Depth feet
Devonian		Missing	0–25
		Limestone, medium grey	25–40
		Limestone, brownish grey	40–50
		Limestone, medium grey	50–60
		Limestone, brownish grey	60–70
		Dolomite, cream coloured to white	70–340
		Dolomite, grey to brown	340–360
Silurian		Dolomite, reddish brown and buff-red	360–370
		Dolomite, buff	370–380
		Dolomite, cream coloured	380–390
		Dolomite, dark buff to grey	:90–420
		Dolomite, cream and reddish brown	420–430
		Dolomite, cream and pink	430–440
		Dolomite, reddish buff	440–450
		Dolomite, cream coloured	450–460
		Dolomite, cream and rose	460–470
		Dolomite, cream and light pink	470–480
		Dolomite, cream to grey	480–520
		Dolomite, pink	520–530
		Dolomite, cream to white	530–870
?		Missing	870–900
Ordovician	Stony Mountain	Dolomite, medium grey	900–1,000
	Red River	Dolomite, cream coloured	1,000–1,075
		Dolomite, light buff, some limestone	1,075–1,210
		Dolomitic limestone, light buff	1,210–1,220
		Dolomite, buff, some limestone	1,220–1,260
		Dolomitic limestone	1,260–1,270
		Dolomite, buff, some limestone	1,270–1,330
		Sandstone with a little dolomite	1,330–1,340
	Winnipeg	Shale, grey	1,340–1,360
		Shale, brownish grey	1,360–1,365
		Missing	1,365–1,380
		Shale, brownish grey	1,380–1,400
		Shale, greenish grey	1,400–1,410
		Sand, buff and brown, some grey shale	1,410–1,425
		Sand, white quartz, well rounded, coarse	1,425–1,435
		Shale, greenish grey	1,436
		Sand, white quartz, well rounded, coarse	1,437–1,444
		Clay (kaolin ?), light greyish green	1,444–1,447
		Sandstone, very coarse, quartz	1,447–1,450
		Sand, medium grain	1,450–1,458
Precambrian		Clay, light greenish grey, and quartz, weathered Precambrian	1,458–1,462
		Sand, medium grained, buff with some brown, iron-stained fragments	1,462–1,468
		Weathered Precambrian rock, grey	1,469
		Weathered Precambrian rock, brown	1,469–1,473

Although the distance between the Winnipegosis and Dauphin wells is only about 35 miles, there are marked differences in parts of the Devonian and Silurian sections. The Winnipegosis well starts in the Devonian at an horizon believed to correspond to that at 670 feet in the Dauphin well. The beds at the assumed positions of the Devonian-Silurian contact are not quite the same, possibly the lower part of the Devonian and the upper part of the Silurian as shown in the Dauphin well are missing in the Winnipegosis well.

The drawing of the boundary between the Silurian and Ordovician is based on the change of colour and the occurrence of the same species of *Sceptropora* as were observed in the Stony Mountain formation in the Stony Mountain and Manitou wells. Whether the top of the Stony Mountain is missing or not is uncertain, due to a gap in the samples between 870 and 900 feet. Although the Stony Mountain formation appears to have about the same thickness in the Manitou and Winnipegosis wells the Red River formation is 123 feet thinner in the Winnipegosis well. The sandstone at 1,330 to 1,340 feet is assumed to form the basal bed of the Red River formation. The contact of the Winnipeg formation with the Precambrian is difficult to locate because of the transitional character of the rocks, due to weathering. Undoubtedly the last few samples are weathered Precambrian rock.

MAFEKING NO. 3 WELL

Drilled by Edward Doherty and associates

Location: L.S. 12, Sec. 2, Tp. 43, Range 26, W. 1st Mer.

The samples from 0 to 220 feet represent the Upper Cretaceous and whatever Mesozoic beds may occur in the sand below them. The samples from the Palæozoic are all core samples.

—	—	—	Depth feet
Devonian		Dolomite, cream coloured	230–300
		Missing	310
		Dolomite, light buff	320–330
		Dolomite, medium grey	340
		Dolomite, dark buff	350–370
		Dolomite and shale, reddish brown	380
		Dolomite, medium grey, shaly	390–470
		Dolomite, buff to grey, porous	480–490
		Dolomite, medium grey	500
Silurian (?)		Dolomite, shaly, reddish brown	510–520
		Dolomite, medium grey	530
		Dolomite, white, very porous	540
		Dolomite, light buff, porous	550
		Dolomite, light buff	560–640
		Dolomite, light buff, very porous	650
		Dolomite, cream coloured	660–690
		Dolomite, medium grey	700
		Dolomite, cream coloured	710–720
		Dolomite, mottled, brownish grey	730
		Dolomite, cream coloured, slightly porous	740–800

—	—	—	Depth feet
Silurian		Dolomite, reddish brown	810–820
		Dolomite, cream coloured	830
		Dolomite, buff, porous	840
		Dolomite, pink to rose	850
		Dolomite, light rose and buff	860
		Dolomite, streaked rose and buff	870
		Dolomite, light greyish buff, hard, compact	880–890
		Missing	900
		Dolomite, light greyish buff	910
		Dolomite, white, compact, conchoidal fracture	920
		Dolomite, light greyish buff, conchoidal fracture	930
		Dolomite, cream coloured, compact, conchoidal fracture	940
		Dolomite, cream coloured, porous	950–960
		Dolomite, light buff, nearly white, compact	970–990
		Dolomite, light buff, many fine grains of sand embedded in the matrix	1,000
		Dolomite, light buff	1,010–1,080
Ordovician	Red River	Dolomite, light buff, but darker than above and somewhat mottled or streaked and porous	1,090, 1,170
		Dolomite, grey and light buff	1,180–1,190
		Dolomite, buff	1,200
		Dolomite and limestone, cream	1,210–1,220
		Dolomite, buff	1,230–1,240
		Dolomite, buff and white	1,250
		Dolomite and limestone, buff	1,260
		Dolomite, light buff	1,270–1,280
		Dolomite, medium grey	1,290
		Dolomitic limestone, light buff	1,300
		Dolomite, buff and grey mottled	1,310–1,330
		Missing	1,340
		Dolomite, buff and grey mottled	1,350
		Dolomite, buff and some mottled	1,360–1,520
	Winnipeg	Sand, buff, grey	1,520–1,570
Precambrian		Granite, pink, foliated	1,573–1,580
		Granite, dark grey, foliated	1,590
		Granite, pink, foliated	1,600
		Granite, dark grey, foliated	1,610
		Granite, pink, foliated	1,620–1,630

The Devonian beds were identified by the presence of *Atrypa* cf. *reticularis* (determined by E. M. Kindle) in samples at 340 feet. In the Porcupine well, which passes through a similar section, the samples from the Devonian contained a number of distinctive ostracods belonging to a species not found in wells studied from other localities. This peculiarity of fauna may indicate that the Porcupine well section has certain members of the Devonian not represented elsewhere. The top and bottom of the Devonian as found in the Dauphin well are not present in the Mafeking well.

The position of the boundary between the Devonian and Silurian in the Mafeking well is somewhat uncertain. Fossils found at 540 feet were identified by E. M. Kindle as *Glassia variabilis*? and *Straparollus* sp. These fossils suggest a Silurian age for the rocks. If this is the age, the boundary probably should be placed at the top of the red beds at 510 feet. Dr. S. R. Kirk after examining the log of this well suggested that the Devonian-Silurian contact should be placed at the top of the red beds at 810 feet. This would make the thickness of the Silurian agree more closely with the thickness he has observed for the same beds farther east, and the dip would be practically the same as the regional dip observed elsewhere. Some of the hard, white, compact dolomite at 920 feet resembles that described as the lithographic limestone at Grand Rapids.

The position of the contact between the Silurian and Ordovician is problematic. A sample from 1,040 feet contains specimens of a large *Leperditia* which resembles those found by Tyrrell in the vicinity of Grand Rapids. A sample from 1,000 feet is of medium-grained, well-rounded sand in a matrix of dolomite and resembles an horizon noted by Tyrrell.[1] The buff dolomite between 1,090 and 1,170 feet may be the lowest beds described by Tyrrell[2] from the lowest part of the Silurian observed by him. No traces of fossils were found in the samples from this zone. If these beds are the same as those seen by Tyrrell, the contact of the Ordovician and Silurian is around 1,180 feet. The change in colour from the lighter, typical Silurian rock to dark rocks is most marked at 1,080 feet, and it may be that this change marks the contact between the Silurian and Ordovician. In any case the rocks between 1,080 and 1,170 feet resemble those described by Tyrrell more than they do the Stony Mountain and there is no indication of any Stony Mountain strata being present, and, therefore, the beds in question are either Silurian or upper Red River. The writer is inclined to consider them as belonging to the former.

The contact between the Red River and Winnipeg formations probably occurs at the top of the sand at 1,520 feet.

The Winnipeg formation, if present at all, is much thinner than in the other wells. The complete absence of shale between the sand and the overlying dolomite may indicate that the Winnipeg formation is not present, and that the sand is a basal bed of the Red River formation. The very fresh condition of the Precambrian granite is unusual; in all the other wells the Precambrian appears to be much weathered.

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[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept. 1889-90-91, vol. V; pt. E, p. 149 (1892).

[2] Tyrrell, J. B.: Ibid., p. 147.

DEEP BORINGS IN THE PRAIRIE PROVINCES

By W. A. Johnston

(Geologist-in-Charge, Division of Pleistocene Geology, Water Supply, and Borings)

In 1933 borings made in search of oil and gas in the Prairie Provinces were confined largely to Alberta, as has been the case for many years. Owing to the fact that structural conditions in the bedrocks are more easily determined in the western part of the Plains region, and to the occurrence of well-established fields such as Turner Valley, most of the drilling has been done in the west. Much of southern Saskatchewan and southern Manitoba is so deeply drift covered that determinations of favourable structures in the bedrocks are difficult or impossible in many places, except by test drilling or possibly by geophysical methods. A number of borings, however, were undertaken in Saskatchewan in 1933 and when completed should furnish considerable information regarding the sub-surface geology, and oil and gas possibilities of the region.

In Alberta forty-five wells were drilled, samples of which were received by the courtesy of the Department of Lands and Mines of the Government of the Province of Alberta. The samples had been examined by that department and logs of the wells supplied to the operators.

Through an arrangement with the Department of Natural Resources of the Government of the Province of Saskatchewan, samples from wells being drilled in that province and the driller's logs were received. The samples were examined by this division, and the geological logs of the wells supplied to the Government of the province and to the companies.

Near Lone Rock, 17 miles southeast of Lloydminster, the Manito No. 1 well is being drilled by the Altoba Gas Exploration Company, Limited, and has reached a depth of 1,708 feet. Strong flows of gas were struck at different horizons in the Alberta shale. Samples from the well showed the depth to the top of the Alberta shale to be about 1,080 feet. Location of the well was made from the results of drilling a number of test wells to determine the structure. The structure is described by G. S. Hume in the second edition of "Oil and Gas in Western Canada" under the title of the Lone Rock anticline.

In the Lloydminster Gas Company's No. 1 well, three-quarters mile north of the town on the Saskatchewan side, the top of the Alberta shale was reached at about 1,030 feet. Judging by the Ribstone field to the south, gas flows may be looked for at several horizons in the Alberta shale and in the Lower Cretaceous below. The oil sand in the Lower Cretaceous in the Ribstone field is about 900 feet below the top of the Alberta shale. It is not definitely known whether any favourable structure exists in the vicinity of Lloydminster as the area is heavily drift covered, but the records of a few shallow wells in the vicinity afford some evidence that the area is structurally high. A flow of gas having a closed in pressure of 350 pounds was struck in the Alberta shale at 1,380 feet. Drilling is being continued.

About 6 miles south of Cummings on the Canadian Pacific Railway near the Alberta-Saskatchewan boundary, the Twin Provinces oil well No. 1 is being drilled. In this area there is a small thickness of the Bearpaw shale at the surface. The log of the well should approximate that of the Boundary well which, according to an examination of the samples by R. T. D. Wickenden, showed the Belly River to be 900 feet thick, the Pakowki and Milk River equivalent 870 feet, the Alberta shale 1,300 feet, Lower Cretaceous 630 feet, and the Jurassic at least 200 feet. In this well sands were penetrated in the Belly River and at the base of the Alberta shale. There was one sandy zone in the Lower Cretaceous and one at the base. There were no sands in the Jurassic, but the base may not have been reached.

Avonlea No. 1 well, being drilled by Pine Hills Petroleum, Limited, in the Dirt Hills 30 miles south of Moose Jaw at a locality where geophysical tests had indicated favourable structural conditions at depth, reached a depth of 2,945 feet when work was suspended for the winter months. Some gas was found at 1,600 feet in sands that probably are the equivalent of the Belly River of the western part of the Plains region.

The Simpson Oil Company, Limited, who have been producing salt from their No. 1 well, have started a second well.

In Riverhurst area a well situated 4½ miles north of Riverhurst has been started by the Mammoth Oil and Gas Company.

The McDonald well, located near Bridgeford, was put down to a depth of 520 feet. Marine sands 150 feet thick were passed through in the upper part of the well, and the lower part was in shale with some sandy horizons. The beds appear to belong to the Bearpaw formation. Whether sands equivalent to the Belly River occur below the Bearpaw in this region is not definitely known.

In the Hudson Bay Junction area, near the Saskatchewan-Manitoba boundary, drilling was done by the Trail Blazer Oil and Gas Company, Limited. Their No. 1 well is located on Red Deer River about 6 miles southeast of the Junction. A number of wells have been drilled in this district during the past two years with the object of determining structure favourable for the accumulation of oil or gas in the "Dakota" sandstone which lies at the shallow depths of 150 feet to over 300 feet, the depth gradually increasing towards the southwest, and is overlain by the Ashville (Benton) shale. No important flows of gas or oil have been reported as yet from the area.

In southern Manitoba drilling is being done by Croyden Developments under the direction of G. A. MacPherson. A number of test borings to determine structural conditions were made in the area to the south of Manitou. A core of the first hole to a depth of 400 feet was obtained, and drilling is being continued by rotary drill.

A geological interpretation by R. T. D. Wickenden of recent borings in Manitoba is given elsewhere in this report.

OTHER FIELD WORK

Geological

G. S. Hume. Mr. Hume, with R. T. D. Wickenden, mapped a strip of country along the trail leading from Morley to Red Deer River, in the foothills region of western Alberta. The area studied includes the structure on Red Deer River being tested for petroleum.

Topographical

J. W. Spence. Mr. Spence completed a detailed topographical survey, on a scale of 1 inch equals 800 feet, of the Canmore area.

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The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are four parts, A, B, C, and D. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.