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Clay and Shale Deposits of the Western Provinces

(PART V)

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INTRODUCTORY.

Developments have taken place so rapidly in late years over such large areas in the western provinces that it seemed advisable to give, if possible, general information regarding the clay and shale resources of the region as a whole, instead of confining the investigations to detailed work in any special portions. The present report and the accompanying report, as well as the three previous parts already published, are an attempt to give a general account of the distribution of the clay and shale deposits in the four different provinces, as well as all the information possible regarding the technology of these materials.

The investigations to be undertaken subsequently will cover in a more detailed manner those areas in which materials of exceptional value have been found to occur during the previous examinations, or those districts where industrial centres are likely to develop owing to economic reasons. Certain outlying districts which have hitherto been inaccessible, will soon be provided with railway communication, and their resources brought within the bounds of development.

Most of the materials reported on have been sampled by the writers in the field, but included in the present report are several tests on clay samples submitted from outside sources to the laboratory for examination. These materials were generally small in amounts, and as a rule were not accompanied by any description of the extent or occurrence of the deposit from which they were taken. Such tests are generally of little value, as the sample selected may not give the true value of the average character of the deposit, or a sample may be taken from a deposit too small in extent to have an economic value in an industry.

Attention is directed to the chapter on drying of clays in this report. Many clays in the Great Plains region of western Canada have defective drying qualities, and the tests for drying should be one of the first points determined in their examination.

Considerable time has been spent by the writer in devising a method to overcome this defect, which will be practical in its application, and experiments with this end in view are still in progress.

EXPLANATION OF CONES.

Seger pyrometric cones were used for control of temperature in burning when making the tests for these reports. Their composition and use are fully described in Memoir 24. These cones are small triangular pyramids, about one-half inch in dimension at the base, and 3 inches long, tapering to a point. The cone bends in time, under the influence of heat, until the point touches the base which supports it when placed opposite the peep-hole in the kiln. The bending of the cone is an indication that the required heat, whatever it may be, has been arrived at and firing is stopped. Two or three cones, with softening points 20 degrees C. apart, are generally set up in a row, when used in practice. This is the simplest and cheapest method of obtaining and controlling kiln temperatures.

Pyrometers are also used in most of the larger plants. The following is a partial table of cone numbers, and their equivalent softening points in degrees. It will be found useful for reference in connexion with this report.

No. of cone.	Fusing point.	
	Degrees F.	Degrees C.
010	1742	950
09	1778	970
08	1814	990
07	1850	1010
06	1886	1030
05	1922	1050
04	1958	1070
03	1994	1090
02	2030	1110
01	2066	1130

No. of cone.	Fusing point.	
	Degrees F.	Degrees C.
1	2102	1150
3	2174	1190
5	2246	1230
7	2318	1270
9	2390	1310
10	2426	1330
12	2498	1370
15	2606	1430
20	2786	1530
25	2966	1630
26	3002	1650
27	3038	1670
30	3146	1730
31	3182	1750

The cones used in the different branches of the clay-working industry in the United States and Canada are approximately as follows:

Common brick....................	012–01
Paving brick......................	01–5
Sewer-pipe.........................	1–7
Buff face brick..................	1–9
Hollow blocks and fireproofing......	07–1
Terra-cotta........................	02–7
Conduits............................	5–8
Firebricks	5–14
White earthenware................	8–9
Red earthenware..................	010–05
Stoneware..........................	6–8
Porcelain...........................	11–13
Electrical porcelain...............	10–12

Clay and Shale Deposits of the Western Provinces.

PART V.

CHAPTER I.

MANITOBA.

PLEISTOCENE.

Sprague.

Five samples of clay from a farm in this vicinity were submitted to the laboratory for testing. No data regarding the thickness of the deposit, or character of overburden, if any, were sent. Four of the samples were nearly alike in character, being taken from different pits, and may be treated as one. They were yellowish, sandy, calcareous clays, requiring 20 per cent of water for tempering. Their plasticity was fairly good so that they could be made up into smooth, hollow, round tile in a hand press. Their drying qualities were not good, it requiring about 5 days to dry a full sized brick at room temperature; if forced to dry at a faster rate than this, the brick will check, and becomes useless. The drying shrinkage is from 5 to 6 per cent. These clays burn to a salmon coloured rather porous body at cone 06, with an absorption of 18 per cent. When burned to cone 1 the body is buff coloured, and denser, the absorption being 13 per cent. There is no shrinkage in burning; on the contrary, a slight swelling takes place during this operation; this being a frequent occurrence with clays having a high lime content.

These clays will make very good buff-coloured building brick by the soft-mud process, and it is possible that hollow brick or drain tile can be made by stiff-mud machine. The drying is their weak point, but by slow drying and protection from hot winds, they can be dried intact.

In order to secure a hard durable product, the burning must be carried to the temperature of cone 1 or nearly so. The clay contains enough small lime particles to cause underburned wares made from it to disintegrate; hence it is an unsafe material to use unless fully burned.

These clays, in general, are similar to those worked for brickmaking at Morris, Winnipeg, and Balmoral, and are representative of the brick clays of the Red River valley, in Manitoba, as described in Memoir 24.

The fifth sample submitted from Sprague was a stiff, highly plastic and sticky, bluish grey clay, which underlies the yellow calcareous clay. It burns to a dense red body at low temperatures, and is non-calcareous. This material is of no value for brickmaking purposes, as it cracks badly in drying, warping, and shrinking to a high degree as well during this process.

A similar clay underlies all the buff-burning clays, at the other localities mentioned above.

Winnipeg.

The material used for brickmaking in the vicinity of the city of Winnipeg consists of about 3 feet of buff-burning clay. Underlying this thin sheet is about 40 feet of red-burning blue clay, which is unworkable in the raw state on account of its extreme toughness, stickiness, and tendency to crack and warp in drying. Many attempts have been made to utilize this clay but without success.

The ante-fired process has been suggested as a possible means of overcoming this obstacle to using it. This consists in calcining the clay, as it is dug from the pit, in roast heaps, using either wood or coal for fuel. The calcined clay is then ground in dry pans to pass a 12 mesh sieve. The ground, burned clay is mixed with 5 or 6 per cent of hydrated lime, and pressed into brick shapes, which are hardened in a cylinder under steam pressure. The process is similar to that used in the manufacture of sand-lime brick. The resulting brick has the colour of the burned clay and is much more porous than a sand-lime brick.

Some test brick were made by this process in the laboratory and submitted to crushing and freezing tests. The results of these tests showed that the nature of the bond produced was as good as that in sand-lime brick.

A method of using the clay in the raw state may be obtained by the use of caustic lime. The addition of about 3 per cent of this ingredient has a remarkable effect. It destroys the stickiness, reduces the plasticity, makes the wet body workable, and assists in drying. As far as the experiments in the effects of quicklime have proceeded, they show that while the clay may be rendered workable by its use, it seems to cause a weakening of the burned body. It also increases the tendency towards scumming.

Mafeking.

A sample of yellow surface clay from the lower slopes of Porcupine mountain in the vicinity of Mafeking was sent to the laboratory for examination. This is a highly calcareous, gritty clay which required 30 per cent of water for tempering. It is fairly plastic but works rather short, being liable to tear in moulding. It burns to a salmon-coloured porous body at cone 06, but becomes buff-coloured when burned to higher temperatures. The clay contains enough coarse lime particles to cause the underburned wares to disintegrate in time, due to air slaking of the lime. It would be suitable for the manufacture of common brick if burned to a temperature between 2000 degrees and 2100 degrees F.

CRETACEOUS—PIERRE AND NIOBRARA.

Shales of Cretaceous age extend from the Pembina river at the International Boundary, northwestward along the base of the Pembina, Riding, Duck, and Porcupine mountains.

In Manitoba this system contains in ascending order the Dakota, Benton, Niobrara, and Pierre. The general characteristics and several tests of these materials are given in Memoirs 24 and 25.

Virden.

The Pierre shales which occur on the upper part of east Assiniboine hill about 4 miles north of Virden, were reported on a few years ago. This shale is non-plastic when finely ground and mixed with water, so that it cannot be moulded into shape. It burns to a red colour and to a light weight porous body at all temperatures up to cone 5. This is the most refractory material at present known in the province, as it is not fused at cone 15 (1430 degrees C.) requiring a rather higher temperature to do so; but it is not a fireclay.

Some samples were received for testing recently from this neighbourhood, but higher up the valley of the Assiniboine, the locality given being the S.E. ¼ of sec. 14, tp. 11, range 25. The samples were taken from pits in the valleyside, one at 15 feet below the prairie level, and another at 150 feet below. Both of these samples were dark grey, rather soft and flaky shales, entirely different from the Pierre shales described above, being highly plastic, sticky materials, when ground and tempered with water. They burn to a dense body with a red colour at low temperatures, but the test pieces bloated unless fired very slowly. They also have a large drying shrinkage, accompanied by warping and cracking, even in the small bricklets.

These shales by themselves do not appear to have any value for the manufacture of clay products, but a small quantity of them might be mixed with the non-plastic Pierre shales to render the latter workable in wet-moulded processes.

Another sample was a light greenish grey, soft material taken from a test well sunk by the town of Virden within the town limits. This well passed through 65 feet of surface clay, sand, and gravel, and at 70 feet below the surface struck a thin layer of the substance referred to. This was probably bentonite or soap clay, an exceedingly plastic, fine-grained material, mostly colloidal matter. It has a small commercial value when in large quantities, easily accessible. It is described in Memoir 25, page 89.

Leary.

Leary is a station on Pembina mountain on the line of the Canadian Northern railway. A dry-pressed brick plant has been in operation here for some time; it is described in Memoir 24. An effort is now being made to utilize the shale of the Niobrara formation in this vicinity for the manufacture of sewer-pipe. Two carloads of the shale were shipped to the Ontario Sewer Pipe company's works at Mimico for the purpose of making a test on a commercial scale. It is a soft dark grey, almost black shale, containing particles of gypsum and some carbonaceous matter. It burns to a dense red body at cone 03, and begins to soften at about cone 6. The shale grinds easily and is very plastic, coming from the pipe presses with a smooth polished black surface. Its drying qualities are good.

The product turned out of the kiln at the end of the burning was fairly satisfactory for a first trial. On account of the carbonaceous matter, and the gypsum which this shale contains, the burning of wares made from it will be attended by some difficulty. Better results could probably be obtained by mixing some Pierre shale with the Niobrara. The effect of the Pierre shale is to make the mixture more refractory, and give a body which is not quite so dense as with Niobrara shale alone. Such a body would be much easier to burn the carbon from, and reduce the tendency towards bloating and black cores. The quality of the salt glaze produced would also be better on this mixture. This fact was pointed out in Memoir 25, page 93.

Carmen.

A plant for the manufacture of clay products is being erected at Carmen, the clay to be used is that described above from Leary, and coal will be brought from the nearest available field. The advantages of this point are a cheap factory site and good facilities for distributing finished products, as three different lines of railway touch here. Fireproofing, hollow blocks, and sewer-pipe will be manufactured at this plant.

Mafeking.

Two samples of soft, dark grey or black shales received for testing from Porcupine mountain, near Mafeking. No information was sent regarding the thickness of the beds nor whether the deposits could be easily worked. These shales may belong to the Benton division of the Cretaceous, but they resemble the Niobrara shales to some extent. They are quite plastic when ground and mixed with water, one of the samples being quite pasty, and stiff in working. The small test pieces dried without cracking, but full sized pieces probably give some trouble in drying. They burn to light weight, porous, red bodies at cone 03, and melt about cone 4. If burned too fast they swell up into a vesicular mass which will float in water. These shales contain so much carbonaceous matter that they burn with a bright flame like bituminous coal when heated to 500 degrees C.

Test pieces made by the dry-pressed process, had a black core and cracked surface when burned. Whatever else these shales may be adapted for, they do not appear to be of any use for the manufacture of clay products.

DEVONIAN.

The Devonian rocks occur in a narrow strip, extending north from near the International Boundary along the shores of Lakes Manitoba and Winnipegosis. Argillaceous beds are comparatively rare in this formation in Manitoba, the greater part of it being composed of limestone.

German Hill.

The only sample of Devonian shale so far tested in the province was collected by Mr. A. MacLean, of the Geological Survey, from a thick bed at German hill, on the south shore of Lake Winnipegosis. This shale is light red or salmon-coloured, but contains grey rock particles which are probably from thin limestone bands interbedded with the shale. The deposit as a whole is highly calcareous, and is soft and crumbles down at the outcrops. When ground and tempered with water it has good plasticity and works rather smooth. It burns to a cream-coloured soft body like chalk, which falls to pieces very quickly from air slaking. This happens after the material has been burned to 2000 degrees F. It is impossible to use it for the manufacture of clay products, on account of the high percentage of lime it contains.

SILURIAN.

The Silurian rocks cover a rather larger area than the Devonian, and lie principally between Lake Winnipeg and the other large lakes to the west. They are the principal source of the building stone for the city of Winnipeg.

Stonewall.

About 6 feet of red and grey, hard, calcareous shales underlie the lower beds of magnesian limestones or dolomites in the quarry at Stonewall. An average sample of these beds was collected for testing by the writer.

When finely ground and worked up with 14 per cent of water this material developed a fair amount of plasticity, which was unexpected in such a gritty material. It could be moulded into 3 inch round pipe in a hand press. Its drying shrinkage was 3 per cent. It burns to a cream-coloured, soft body with a slight increase in volume, at all temperatures up to cone 3. The absorption at this point was excessive, being about 35 per cent. The shale stands a high degree of heat, probably on account of a large percentage of magnesia, and it does not vitrify until cone 8 is reached. At a little higher temperature than this it will melt suddenly. This material contains such a high percentage of lime that it cannot be burned to a dense body at ordinary temperatures, hence it could not compete with the surface clays of the vicinity, such as those at Balmoral, which burn dense at comparatively low temperatures, and which require no preliminary grinding.

Another bed of shale 10 to 18 inches in thickness occurs 6 feet higher up in the same quarry. The percentage of lime in this bed is also very large, some of it being present in rather coarse particles, after grinding to pass a 20 mesh sieve. This shale works up into a very plastic body when tempered with water. It burns to a cream-coloured chalky body, which rapidly disintegrates in air, and is useless for the manufacture of clay products.

CHAPTER II.

SASKATCHEWAN.

PLEISTOCENE CLAYS.

City of Saskatoon and Vicinity.

The city of Saskatoon and vicinity is underlain by unconsolidated surface deposits, or drift, of unknown depth. The Saskatchewan river has cut a trench to a depth of about 100 feet in the drift materials, without reaching bedrock at any point in this neighbourhood. A boring made while prospecting for gas, near the Grand Trunk Pacific Railway bridge, revealed the fact that soft dark grey shales of Cretaceous age underlie the surface drift. A sample of this shale taken from the bore-hole was tested, but it proved worthless for the manufacture of clay products.

The surface deposits consist essentially of two classes of materials: (1) boulder clay, (2) surface clay. The boulder clay is the lowest member of the drift series; it is a direct glacial deposit, consisting of a heterogeneous mixture of large and small well rounded boulders, pebbles, gravel, and sand embedded in a matrix of clay.

The main portion of the city is built on the boulder clay, which forms the low terrace on the west side of the river (Plate I). Most of the large boulders found strewn along the margin of the river at low water stages, are derived from this deposit. These boulders have been largely utilized for building stone in the city; further than this the deposit has no economic value.

The surface clay which overlies the boulder clay, appears to have been deposited in water having more or less current. It consists of a mixture of silty or sandy yellowish clay, with a dark grey, stiff, highly plastic clay. These two materials are irregularly distributed through the deposit, so that they cannot be separated in working. Occasionally they alternate in horizontal or wavy bands and layers, but the dark clay mostly occurs in lenses or pockets in the silty yellow clay (Plate II A).

As far as could be ascertained in the limited time at my disposal, this type of clay is the only kind available for the manufacture of structural wares within a radius of at least 4 miles from the city.

Exposures on the western side of the Saskatchewan river showing good sections of the surface clays were seen at Elliott's brickyard, in the Canadian Pacific Railway cutting on the Cahill farm, and the Grand Trunk Pacific Railway cutting near the bridge. On the eastern side of the river the material was seen to advantage in the excavation made for the foundations of the Presbyterian college, and at several points on the cut banks of the river.

This clay possesses certain disadvantages which are readily apparent to the clay worker. (1) The stiff dark clay which may be called by the expressive name "gumbo" is hard to work. It does not slake in water, nor mix with the accompanying silty clay in the pug-mill, but remains in lumps. These lumps act like pebbles in the burned brick, being a source of weakness when large in size. (2) The clay is hard to dry after it is moulded into shape. It has to be handled carefully and slowly during the drying process or the wares will crack. (3) Its softening point under firing is low, so that it can only be used for the common kind of brick, but not for the manufacture of vitrified wares.

The first of these difficulties may be overcome by drying the clay in storage sheds, and grinding it fine in the dry state. This method is effectual in giving an even distribution of the gumbo through the mass, and producing a more uniform body. No machine has yet been devised that will grind the gumbo as it comes wet from the bank.

The drying difficulty is not so easy to overcome. The clay when made up into brick by the soft-mud process can be dried intact on racks and pallets set outdoors, if they are protected from warm winds during the early stages of drying. It would be harder to dry brick made up by the stiff-mud or wire-cut process, owing to the denser body in this class of ware. Porous fireproofing or drain tile may be easier to dry than brick, owing to the comparatively thin walls in these wares. In making any class of wares, however, hurrying the drying process would probably result in serious losses.

The clay may be rendered more workable by the preheating process, which consists briefly in passing the clay through a rotating cylinder and applying a heat of 400 degrees to 500 degrees C. The preheating of the raw clay destroys the stickiness, and makes it easier to dry. A clay that cracks can be changed to a fast drying clay by this treatment. As the Saskatoon clays are of low grade, suitable only for the manufacture of common brick, it is doubtful if this method could be applied economically.

The addition of sand would assist the drying, but as the clay burns to a rather porous body, the sand would tend to weaken it. A better plan would be to grind up waste brick to add to the clay, as this would not interfere with the density or structure of the burned body.

Tests of the Clay.

A sample was taken from the cutting on the Grand Trunk railway, about half a mile east of the river. About 20 feet in depth of clay is exposed here, consisting of sandy or silty clay, with layers or wavy bands and pockets of stiff dark clay irregularly distributed.

The clay contains a rather high percentage of lime, effervescing violently in dilute hydrochloric acid. There are no pebbles or coarse grit particles present. This sample (Lab. No. 142) was ground fine enough to pass through an 8 mesh screen, and tempered with 23 per cent of water. It formed a very plastic rather sticky mass, but will pass through a lubricated machine die without tearing.

A 3-inch cube made up for a drying test, cracked at a temperature of 80 degrees F. A full sized brick was placed to dry in the room temperature of 65 degrees to 70 degrees F. It requires 7 days to dry, without cracking. The drying shrinkage was 7 per cent. The dried brick showed the grains of gumbo, which had not slaked during the tempering or moulding.

The clay burns to a pale red colour at cone 010, without any fire shrinkage, the body was very porous, the absorption being 18 per cent.

When burned to cone 06 (1880 degrees F.) the colour is rather deeper and the body denser, the absorption being 14·7 per cent. The brick becomes steel hard at this temperature.

If burned to cone 03 (2000 degrees F.), the absorption is reduced to 9 per cent, the fire shrinkage is 1·4 per cent, and the colour a little better. The clay melts at cone 3 (2174 degrees). The colour is not good at any stage of burning, although the brick at cone 06 were burned in a down draft kiln at the Don Valley brickworks at Toronto, under partly reducing conditions which ought to develop the best red colour in clay, if it is red-burning. The colour is obscured by the unsightly dirty white scum, which is due to a soluble salt of lime or magnesia brought to the surface during drying.

This clay is suitable for the manufacture of common brick, if made by the soft-mud process. On account of the drying difficulty the stiff-mud or wire-cut process is not recommended, as bricks made by this process are harder to dry. If the clay is used directly as it comes from the bank and simply passed through a pug-mill to the machine it will make brick similar to those produced in Mr. Elliott's brickyard, which is the best that can be done under these conditions. The lumps of gumbo, which appear like pebbles, can be seen in these brick. The gumbo has a higher shrinkage than the silty clay, so that it draws away from the body and produces lines of weakness.

If the clay is ground when dry, the gumbo is uniformly distributed through the mass, and the burned product is sound in structure, if fired to a temperature not less than 1850 degrees F.

A small sample for testing was taken from the highest part of the bank of the Saskatchewan, at the cemetery, on the east side of the river. This clay (Lab. No. 141) does not contain nearly so much gumbo as the other sections seen in the city. When tempered with 22 per cent of water, it forms a fairly plastic and easily worked body. It contains no pebbles or fine grit. This clay was not tested for fast drying, as the sample was too small. The drying shrinkage of the bricklets made from it was 6·5 per cent.

It burns to a red colour at cone 010, with a hard body, and an absorption of 13 per cent. At come 06 (1880 degrees F.) the colour is a very fair dark red, with a steel hard body. The fire shrinkage is zero, and the absorption 11 per cent. When burned to cone 03 (2000 degrees) a fine clean dark red colour is produced, the body is very hard and dense, the fire shrinkage being 1 per cent, and the absorption 9 per cent.

This is the best brick material of any of the clays examined. The colour is good, and free from the objectionable scum which develops on the others. It produces a sound hard body, well adapted for weight carrying purposes in large structures.

The next sample was taken from W. O. Miller's farm about 15 miles southwest of the city of Saskatoon, on the bank of the Saskatchewan river. This property is situated on the flood-plain of the river, the level of the plain being about 15 feet above medium stage of water. The clay here consists of re-worked surface materials deposited by the river, during flood time. The river has since cut down through it. The material is very sandy, and contains no gumbo. It is highly calcareous.

This clay (Lab. No. 143) when tempered with 23 per cent of water, works up into a short rather flabby body of medium plasticity. It differs greatly from the stiff, sticky, gumbo clays, and will stand fast drying. The drying shrinkage is about 4·5 per cent.

It burns to a salmon coloured body at cone 010 (1842 degrees F.), very porous, but hard. When burned to cone 06 (1880 degrees F.) the body is still very porous, the absorption being 18 per cent. The fire shrinkage is zero. If burned to cone 03 (2000 degrees F.) the body becomes denser, but the absorption is still high—13 per cent, and the colour changes to buff. The clay melts at cone 3 (2174 degrees F.). The full sized brick submitted was burned in a down draft kiln at the works of the Don Valley company of Toronto.

This material will make common brick by the soft-mud process. It has the merit of standing fast drying without cracking, but the colour is poor and the body rather light and porous.

A material which resembles marl was seen on the shore of Pike lake about 22 miles southwest of the city of Saskatoon, and also on John Forbes' farm about 2 miles nearer town. The material is light grey in colour, and contains numerous shells. It is not a marl, however, as the content of lime (only about 15 per cent) is too low: some small brick of the material were made and burned. A soft crumbling body resulted in burning, which was too weak to be of any use. This material appears to have no economic value, and only occurs in thin layers.

Floral.

A plant for the manufacture of common brick by the stiff-mud process was in operation at this point for the first time during the summer of 1913. It is situated on the Canadian Pacific line, about 6 miles east of the city of Saskatoon.

About 10 to 12 feet of clay is exposed in the pit excavated for brickmaking (Plate III). It is a stratified deposit, of yellowish colour with occasional streaks of exceedingly stiff dark grey material. Small particles of gypsum are scattered through the deposit, but there are no pebbles or coarse grit.

The clay works well and flows through the die of the machine in a smooth bar which is cut by the wires into an almost perfect brick. The drying qualities of the clay are poor, all attempts to dry the green brick without cracking having failed up to the time of my visit in August. The plant is equipped with a Betchel dryer, but the brick cracked in this dryer even when no heat was admitted. A sample of clay taken from this locality burned to a good red colour and hard body at 1850 degrees F., but it was impossible to dry any large sized pieces made from it. There is no sand in the vicinity of the plant, and it is doubtful if the addition of sand would improve the drying, unless by using a large quantity, which would weaken the burned body too much. The pre-heating treatment seems to be the only remedy for overcoming the difficulties in this clay, but it is not of high enough grade to warrant the expense of this treatment.

The tests of the clay were made for the Company that erected this plant, by a firm of clayworking machinery makers in the United States, and the sample brick submitted were satisfactory in every respect. No guarantee, however, was given that the plant could produce similar brick under working conditions.

Davidson.

A sample of Pleistocene clay was received from this point on the Regina branch of the Canadian Northern railway from the manager of the Davidson Clay Products company. This clay is very plastic and has good working properties; it is free from pebbles and coarse grit, but contains numerous crystals of selenite. It burns to a fairly hard red body at low temperatures, but it cracks so badly in drying that it cannot be used for brickmaking by any of the ordinary processes, even with the addition of 33 per cent of sand.

An effort will be made to use this clay by what is known as the ante-fired process, which consists in first calcining the clay in heaps as it comes from the bank, using either wood or coal for fuel. The calcined clay is ground in dry pans, mixed with a small percentage of lime, then pressed into brick shapes, which are hardened in cylinders under a pressure of 120 pounds of steam. It will be noted that the method of procedure after the burned clay is ground is the same as in making sand-lime brick. This process is in the experimental stage at present, but it may provide a means of working those clays that crack in drying.

Bruno.

A small brick plant for the manufacture of common building brick was erected at this point on the Canadian Northern railway in 1913. A sample of the clay to be worked at this locality was submitted to the laboratory for examination. It is a yellow-coloured, highly calcareous clay, apparently free from pebbles or coarse particles. When tempered with 25 per cent of water, it works up into a mass of fair plasticity. The shrinkage on drying was 5 per cent. The fast drying qualities are not good, but it can be dried slowly with safety. It behaves as follows in burning:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0	27	salmon
06	0	29	salmon
03	1	25	buff
1	1·3	22	buff

It is a typical calcareous clay, burning to a soft pink porous body at lower temperatures, becoming slightly denser and buff-coloured when burned higher. A good common brick made by the soft-mud process can be made from this clay, but they must be burned nearly to cone 1 (2100 degrees F.) in order to secure the best results.

Kamsack.

The plant of the Kamsack Brick and Tile company is situated about a mile east of the town on the Canadian Northern Railway line. The clay is taken from the sloping ground of a small river valley. It is a yellowish stratified clay, 8 to 10 feet in thickness, fairly free from pebbles. It is overlain by 1 or 2 feet of gravelly clay, and underlain by Cretaceous shale, which is described later on.

The clay requires 24 per cent of water for tempering; its plasticity and working qualities are fairly good. The drying shrinkage is 6 per cent, and the drying must be done slowly, as the clay is liable to crack if forced. The results obtained in burning are as follows:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0·2	23·8	light red
06	0·2	22	light red
03	1·5	18	buff
1	4	12	buff
3	softens		

This clay will make good common brick by the soft-mud process, but it must be burned to a temperature of not less than 2000 degrees F. (cone 03), otherwise the brick will be too soft, and unsafe for use. Its lime content is rather high, so that it melts rapidly soon after vitrification begins, but it is not necessary to burn to a higher temperature than cone 1 (2100 degrees F.).

A good rule to observe in working these calcareous clays is to produce a good strong yellow colour in the burned product. The pink colour is an indication of underburning. When carbonate of lime exists in coarse particles or pebbles in a clay, they are usually fatal to the permanency of the brick made from it, but hard burning reduces the loss from this source.

LARAMIE FORMATION.

The Laramie formation underlies a large triangular area in southern Saskatchewan. The base of this triangle forms the southern boundary of this province, as far west as the Wood Mountain district, which is included in it. From the apex of the triangle a narrow belt extends northwestward to a little beyond the main line of the Canadian Pacific railway west of Moosejaw. This area includes the Souris coal fields and the Dirt hills. Detached areas are found north and west of this, where the Laramie formation occupies the summits of some of the plateaus and portions of elevations such as the Cypress hills.

This area is of importance because it contains at many localities white or light grey sandy fireclays, and other deposits of a similar nature, which do not stand quite so much heat, called semi-refractory clays. The fireclays of this region have fusing points between cone 27 (1670 degrees C.) and cone 32 (1750 degrees C.), while the latter fail in the fire tests at cone 15 (1430 degrees C.) to cone 25 (1630 degrees C.).

Certain deposits of these types have been described in the two reports on western clays already published. Some additional localities discovered during the season of 1913 are given in the following pages, along with other deposits of less value, from the same formation. Most of the samples referred to were collected by Mr. Bruce Rose, of the Geological Survey. Further details concerning the extent and relationship of these deposits will be given in his report on the geology of the region.

Brooking.

This (170) is a greyish white soft clay containing an abundance of fine-grained grit. This clay requires 21 per cent of water for tempering, and works into a very plastic body with good working qualities. Its drying shrinkage is 5 per cent, and its drying qualities appear to be good, but this test was not made as the sample was too small.

Cone.	Fire shrinkage. %	Absorption. %	Colour.
06	0·3	15	buff
1	1·6	13	buff
3	1·6	12·2	cream
5	2·3	12	grey
10	4	3	grey
20	fused		

This clay behaves like a fireclay in burning up to cone 5, the body remaining open and the shrinkage low. Numerous fused specks appear on the surface of the test pieces when burned to cone 10.

Although this is not a refractory material, it is nevertheless a valuable clay. It can be used for high grade face bricks, or stove linings. It would probably take a salt glaze and be used in the manufacture of sewer-pipe, or electrical conduits, but would have to be burned to a rather high temperature to secure the necessary density of body. If mixed with a certain proportion of good red, dense burning clay, the temperature of burning for vitrified wares could be reduced, and products made with less expense. It is not quite clear from the description whether this deposit occurs in a workable position, or is of sufficient thickness. The locality given for it is sec. 30, tp. 6, range 18, W. 2nd mer. and near the branch line of the Canadian Northern railway.

Big Muddy Valley South of Bengough.

The valley of the Big Muddy river lies 10 to 12 miles south of Bengough station, on a branch of the Canadian Northern railway. This river has cut down through a series of horizontal beds of clays, sands, and lignites, which are exposed on the steeper sides of the valley (Plate IV). A white sandy clay containing rust coloured lumps, which farmers in the vicinity use as a plaster, occurs near the bottom of the bank. This clay (172) requires 24 per cent of water for tempering, it is very plastic, stiff, and pasty in the wet state. It dries slowly and exudes soluble salts which form a slight scum. The drying shrinkage was 7 per cent. The small test pieces did not crack, but full sized wares may crack in drying. The following results were obtained in burning:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
06	1	12	salmon
1	2·4	8	pink
3	3	7	buff
5	4	5·6	grey
10	4	0	grey
20	fused		

The body is vitrified, develops fused spots on the surface, and becomes slightly vesicular at cone 10. This clay is not so sandy as 170, consequently the shrinkages are greater and it burns to a denser body. It is probably suitable for the manufacture of sewer-pipe, but its drying qualities would have to be carefully tested before a decision to this effect could be made. It works well in the dry-pressed process, and should give a good buff or flashed colour, with a hard body when burned to cone 1. It belongs to the semi-refractory class of clays, and is not a fireclay. A similar clay is said to outcrop at several places along the bottom of the valley of the Big Muddy river. The position given for the above deposit is sec. 31, tp. 3, range 24, W. 2nd mer.

Overlying the white or light grey clays are a series of lignite seams and beds of grey and brownish clays and sands. A sample was taken from one of the clay beds, which had a thickness of 43 feet at this locality. It is a soft, fine-grained, grey clay, containing limonite concretions. It makes a stiff sticky paste when tempered with water. The small test pieces cracked so badly that the test could not be proceeded with. The addition of sand does not cure the tendency to crack, so that the material appears to be useless for the manufacture of clay products, in the raw state. The pre-heating process might be applied to stop the cracking, but as the clay is an easily fusible and rather low grade variety the expense of this treatment would be too great.

A bed of grey sand, 34 feet in thickness, overlies this clay. This sand is actually plastic, forming a rather sticky mass when tempered with 30 per cent of water. It is easily moulded, but the small test pieces crack badly in drying, and burn to a weak red body, which is easily crumbled. The greater part of this deposit is composed of sand grains, mostly quartz, a large percentage of which are coarse enough to remain on a 100 mesh sieve. The small proportion of clay in this mass has the power to cause plasticity, and cracking in drying. It is a natural example of the futility of trying to stop the cracking of some of the Laramie clays of this region by the addition of sand.

Coal Mine Lake, Near Bengough.

About 2 feet of soft grey shale underlies the coal seam at this locality. This clay is highly plastic and sticky, with poor drying qualities. It burns to a dense hard red body at cone 06 with a total shrinkage of 12 per cent, which is excessive. This clay is of little or no value.

Underlying this clay is a bed of yellow silt (179) which works up into a body of rather low plasticity when tempered with water. It has a drying shrinkage of 6 per cent, and can probably be dried safely, without cracking. It burns to a light red, porous but sound body at cone 06, without any fire shrinkage. This material is suitable for the manufacture of common red brick by the soft-mud process. The locality given for these clays is sec. 3, tp. 5, range 23, W. of 2nd mer.

Big Muddy P.O.

Sec. 9, tp. 1, range 22, W. 2nd mer.

A sample of rather hard grey shale (171) which lies on top of a 3-foot coal seam was collected at this point. This clay requires 30 per cent of water for tempering, it is very plastic, smooth, and sticky. Its drying shrinkage is 8 per cent. The small test pieces did not crack in drying, but it is probable that full sized pieces of ware might do so.

It burns to a light red body with rather high absorption at cone 06, and is fused to a slag at cone 3. If the drying difficulty can be overcome, this shale would make good common brick. About 25 per cent of sand could be used to reduce the air shrinkage. It is not a fireclay, nor is it suitable for the manufacture of vitrified wares.

Willowbunch Lake.

(Sec. 35, tp. 5, range 26, W. 2nd mer.)

A bed of massive, fine-grained, grey clay occurs overlying a coal seam at this point. A sample of this clay (177) required 36 per cent of water for tempering. It formed a very plastic sticky mass but the working qualities were fairly good. This clay will probably crack in drying when made up into full size wares, but the test pieces did not. Its drying shrinkage is excessive, being 9 per cent. It burns to a steel hard, light red body at cone 06, the fire shrinkage being 2 per cent, and the absorption 15 per cent. It vitrifies at cone 2, and begins to soften about cone 5. When made up by the dry-pressed process, this clay burns to a very fair red colour, and hard body at cone 06.

The shrinkage is rather high, and the drying qualities poor, otherwise this is a very good, red burning clay. It would be useful to mix with some of the sandy fireclay that occurs in this district, for the purpose of making sewer-pipe or fireproofing.

Verwood.

A bed of dark grey, soft shale, or hard clay occurs in sec. 28, tp. 7, range 27, W. 2nd mer. This clay requires the large amount of 45 per cent of water to bring it to a working consistency. It is a very fine-grained material, exceedingly plastic, stiff, and pasty and hard to work in the wet state. It cracks in drying. It burns to a red colour with an excessive shrinkage, and softens at cone 5. It is not a fireclay, and would be a difficult material to handle for the manufacture of any kind of clay product.

A bed of greyish clay 15 feet thick occurs on the Weyburn-Lethbridge line of the Canadian Pacific railway a short distance west of Verwood station. It is overlain by 11 feet of sand. This clay works up so stiff and cracks so badly in drying that it is useless. The addition of sand does not overcome these defects.

Lake of the Rivers.

Deposits of white sandy clay are situated near the north end of Lake of the Rivers, near the Expanse branch of the Canadian Pacific railway, and also near the Avonlea branch of the Canadian Northern railway. Some lignite seams also occur in this vicinity. A sample of the clay was collected by Mr. Rose, the locality given being sec. 14, tp. 11, range 28, W. 2nd mer.

This is a white sandy clay (178), the sand portion is composed of small rounded quartz grains with an occasional scale of white mica. It requires 20 per cent of water to bring it to a good working consistency, its plasticity and working qualities are good. Its shrinkage on drying is 5 per cent, and will probably stand fast drying. Its behaviour in burning is as follows:

Cone.	Fire shrinkage %	Absorption. %	Colour.
06	0	13·8	buff
1	0·3	12	buff
3	1	11·5	cream
5	1	10	grey
10	2	6·4	grey
26	fused		

This material is almost refractory enough to be a fireclay, only failing at 40 degrees C. below the requirements of that class. It stands considerably more heat than 170 or 172, and may be used for many purposes where the demands for refractoriness are not very exacting. It is a valuable clay in the district in which it occurs, and when used alone, or in a mixture with more easily fusible clays, will produce a large range of clay products for structural purposes.

There appear to be two or more beds of clays similar to the above in this locality, as samples from another source were sent to the laboratory for examination, which were said to have come from the same deposits on the Lake of Rivers.

These were greyish white, sandy clays, but not quite so clean in appearance as 178. Both these clays were fused at cone 20, so that they are semi-refractory clays and stand a high degree of heat, but they are not fireclays.

The following chemical analysis made by W. S. Bishop, B A., shows the composition of the two samples of clay from Lake of Rivers:

	1.	2.
Silica (SiO_2)...............	68·17	66·30
Alumina (Al_2O_3)............	21·76	19·02
Iron oxide (FeO)	1·98	5·60
Lime (CaO)................	0·22	0·11
Magnesia (MgO)...........	0·72	0·60
Alkalis (Na_2O+K_2O)......	1·20	not determined
Loss on ignition...........	6·07	7·29

These clays can be used for the manufacture of sewer-pipe and face brick or fireproofing, when mixed with a proportion of more easily fusible clay or alone. There is not much demand for fireclay in Saskatchewan, a clay that works well, dries easily, and with a good range of vitrification in burning, is far more important at present in that province.

Mullrany.

(Sec. 6, tp. 6, range 27.)

A sample of dark grey, hard clay was collected from this locality by Mr. Rose. This is a very fine-grained, highly plastic clay, absorbing the large amount of 44 per cent of water in tempering. It is very stiff and pasty in working, hard to dry, and has high shrinkages. It burns to a hard red body at low temperatures, and begins to soften about cone 3.

On account of poor working and drying qualities, together with abnormally high shrinkages, this clay is not of much value.

Another sample of clay, collected at a point a short distance west of the above, the locality given being sec. 12, tp. 6, range 30, W. 2nd mer., was also tested. This was a grey calcareous rather silty slay, containing rusty lumps. It requires 25 per cent of water for tempering, it worked up fairly plastic, but was rather flabby in the wet state. It is one of the few clays in this region that will stand fast drying by artificial heat, which is probably owing to its lime content as well as to its silty character. The drying shrinkage is 5·5 per cent. It burns to a fairly good light red or salmon-coloured body at cone 06, with an absorption of 11 per cent, and melts to a slag at cone 4. This clay is suitable for the manufacture of common building brick.

Mortlach.

About 7 miles south of Mortlach, on the southwest quarter of sec. 17, tp. 16, range 1, W. 3rd mer., a bed of grey, smooth clay was discovered outcropping on the side of a coulée. It is overlain by a thin seam of lignite, and several feet of glacial stony clay. A shaft which was sunk on the property in search of coal is said to have passed through a thickness of 9 feet of this clay. This clay (153) is very fine-grained and highly plastic when wet, and of a dark grey colour, but bleaches to nearly white when dry. Its shrinkage on drying is rather high, being 10 per cent. The following results were obtained on burning:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
06	1·3	15	cream
03	3·0	13	buff
1	3·0	12	buff
3	3·6	8·4	buff
5	4·3	7·5	grey
10	3·0	vitrified	grey
20	fused		

This material resembles a stoneware clay, but the shrinkage is rather too high for use in the manufacture of stoneware pottery. It stands a fairly high degree of heat, being a semi-refractory clay. It is probably suitable for a high grade face brick made by the dry-pressed process. It would also be useful as one of the ingredients of a sewer-pipe body.

East End.

A small sample of white or light grey clay collected on the bank of Frenchman river, a few miles south of East End, was submitted to the laboratory for examination. No information regarding the thickness of the deposit or its overburden was given. It was a very plastic, smooth clay with good working qualities. It burns to a light grey colour with a vitrified body at about cone 5, and is fused at cone 15. It is one of those semi-refractory clays of the stoneware type.

The white or light grey clays on the Frenchman river and Farwell creek, south of the Cypress hills, were described in the Geological Survey reports nearly 30 years ago. On account of their remoteness from any lines of transportation these clays have hitherto been inaccessible. The Weyburn-Lethbridge branch of the Canadian Pacific railway now under construction will shortly place these clays at the disposal of clay-workers.

Saskatchewan River.

There is a small detached area of the Laramie formation lying just north of the Saskatchewan river, southwest of Elbow. A small sample of clay from this area was received at the laboratory, the locality given being sec. 17, tp. 21, range 10, W. 3rd mer.

It was a light grey, plastic clay which burned to a grey colour and vitrified body at cone 10, and fused at cone 20. It belongs to the group of semi-refractory clays found in southern Saskatchewan, resembling No. 170, from Brooking. No information was given about the extent of the deposit. It appears to be situated at a considerable distance from a railway.

NIOBRARA SHALE.

Kamsack.

The Niobrara shale is found underlying the surface deposits and also exposed at a few points along the Canadian Northern railway, a short distance east of the town of Kamsack. It was uncovered in the bottom of the clay pit of the Kamsack Brick and Tile company, when the surface clay overlying it was removed for brickmaking purposes. The shale is brownish in colour when near the surface, but is dark grey below. It contains a large quantity of selenite or gypsum crystals scattered irregularly through the deposit. The Niobrara shale is soft and can easily be dug out with a spade, but it is much tougher to work in than the overlying Pleistocene or surface clay. This shale when ground and mixed with water forms a pasty mass of high plasticity, which is stiff and hard to work. It shrinks greatly and cracks in drying. It burns to a hard red body at low temperatures, but will swell or bloat unless fired very slowly. If made up by the dry-press process, the drying difficulty is overcome, but the bricks will check in burning. On account of its poor drying and burning qualities this material is not recommended for the manufacture of clay products.

Swift Current.

There are numerous exposures of Niobrara shale in the terrace along the west bank of Swift Current creek, just north of the town, beginning near the hospital. It is dark grey in colour and soft, and may easily be mistaken for a surface clay at the outcrops. It contains a considerable quantity of gypsum in rosettes and flaky slates. This shale is highly plastic and pasty when ground and tempered with water, being also exceedingly stiff and hard to work. It cracks badly in drying, even the small test pieces made from it cracked at ordinary room temperature shortly after being moulded. It burns to a steel hard, red body at cone 010, with a high shrinkage, and melts at about cone 3. This shale is defective in the three most important qualities a clay must have for successful manufacturing, viz., working, drying, and burning.

CHAPTER III.

ALBERTA.

PLEISTOCENE.

There is a large area underlain by stratified Pleistocene clay in central Alberta. It is worked for brickmaking at Lacombe, Red Deer, and Innisfail. It reaches a depth of 40 or 50 feet in places, but its thickness is very uneven as it is laid down on a hummocky surface of boulder clay. Knolls of boulder clay occasionally rise to the surface.

Bullocksville.

There are some good exposures of this clay in the cuttings along the Canadian Northern railway, between Bullocksville and Alix and along the valley of Haynes creek in this vicinity. The deposits generally consist of soft, yellowish, silty layers, interlaminated with harder grey layers of stiff clay. There are occasional bunches and streaks of gravel, but these could be avoided in mining the clay.

An average sample was taken from a bank about 20 feet high in a railway cutting near Stone siding (Plate V B). The clay contains a small percentage of finely divided lime, but no coarse particles or lime pebbles were found in the portion sampled. This clay requires 24 per cent of water for tempering, it works up into a very plastic wet body. Its drying shrinkage was about 8 per cent, which is rather high, but this could be reduced by the addition of about 25 per cent of sand. It behaves as follows in burning:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0·0	18·7	light red
06	0·3	18·5	light red
03	7·0	3·0	red
2	fused		

The clay burns to a good hard body at cone 010, but the colour is better and the body denser at cone 06. The fire shrinkage becomes too great if burned to a higher temperature. The drying qualities of the clay were not tested, but it could probably be dried safely on rack and pallets. It could be used for the manufacture of common brick, by either the stiff-mud or soft-mud process, the latter being the easier to dry. The proper temperature of burning is about 1850 degrees F. The burned bricks become coated with an objectionable white scum, which obscures the colour of the red body.

Mirror.

A small sample of clay from this vicinity was submitted for testing, by Mr. Alex. Mather. It was a buff-coloured, slightly calcareous gritty clay, containing particles of gypsum. It was very plastic, and rather sticky when tempered with water. Its drying shrinkage was only 5 per cent, but its drying qualities were not good. The clay burns to a dense steel hard red body at cone 010, without any fire shrinkage. It stands firing to a higher temperature than the clay from Bullocksville, as it is not softened at cone 1. It is a very good common brick clay, and might also be used for the manufacture of hollow building blocks, if the drying could be accomplished safely. No statement was given regarding the extent of the deposit.

Innisfail.

Common brick are made at this locality by the Innisfail Brick Company (Plate V A). The clay bank at the brick works shows alternate bands of sand, silty clay, and stiff clay, in horizontal layers of 6 inches to 1 foot thick. A proper mixture of these materials seems to make an excellent building brick. There does not appear to be much trouble from cracking in drying, as the green brick come intact from a steam dryer. The brick are made by the stiff-mud process, end cut, some of them being made hollow for partition brick. The burning is done in 3 updraft rectangular kilns, with permanent side walls, the fuel used being dry poplar. The greater part of these brick are sold in Edmonton, and are probably the best common brick made at present in the province of Alberta from surface clays.

Belvedere P.O.

Two small samples of clay from this locality, in tp. 58, range 3, W. 5th mer., were submitted to the laboratory for testing. One sample was a yellowish non-calcareous clay, which was very plastic and stiff and hard to dry in the wet state. It has a large drying shrinkage, and dries very slowly. It burns to a dense steel hard body at cone 010, and fuses at cone 2. This clay will make good common brick, with the addition of 25 per cent of sand, if the drying difficulty is not too great. The other sample was a yellow gritty calcareous clay, not very plastic when wet. This clay swells slightly on burning and gives a very porous chalky body, as the percentage of lime is rather high. When underburned it has a salmon colour, turning to buff when fully burned. It would make a common brick of doubtful quality. A mixture of these two clays would probably give better results than either of them used alone.

Stettler.

The town and surrounding district of Stettler is underlain by Pleistocene clay which for the most part is of glacial origin. Pebbles are scattered freely throughout parts of the clay, but large patches are fairly free from them. A small quantity of red brick were made two years ago at the east end of the town, near the crossing of the Calgary branch of the Canadian Northern railway. A small sample of clay for testing was collected at the roadside about half a mile west of the town. This clay appeared to be free from pebbles, but a section only a few feet below the surface was seen. The clay cracked so badly in drying, that it could not be burned. It is quite probable that the clays in this vicinity are to a large extent defective in this respect.

Vegreville.

Two large samples of clay, taken from different depths to 12 feet below the surface, were submitted for testing by the Vegreville Brick company. Both samples are brownish, non-calcareous, very sandy clays, but free from pebbles of coarse grit. The upper part of the deposit is more sandy than the lower, otherwise it is much the same in character, so that they may be treated as one. The clay is very plastic, but not excessively so, and its working qualities were very good. The shrinkage in drying is about 7 per cent, and the drying qualities are poor. It burns to a very clean red hard body at cone 06, and should produce a good building brick when burned to that temperature. Brick made by the stiff-mud or wire-cut process from this clay would be hard to dry, but soft-mud brick could probably be dried slowly if protected from hot winds on racks and pallets. The clay will crack badly if forced in drying. Some dry-pressed test pieces were made up from this clay, but the results of the burned trials were not very good, as the brick were too soft and porous. Very few Pleistocene clays are suitable for the manufacture of pressed brick.

Medicine Hat.

A new brick plant owned by the Medicine Hat Brick company was built during the summer of 1913 on the site of the old Purmall and Pruitt brickyard (Plate VI B). This plant is designed for a large output of common wire-cut brick. A huge Bonnot special machine with a two-stream, end-cut die, having a capacity of 200,000 brick a day, was installed. A Williams clay crusher will be used to prepare the stiff clay which occurs in their bank. Tunnel driers, heated with gas furnaces, and provided with fan draft are used for drying the brick. The plant will be driven by electricity obtained from the city power house, about 550 horse-power being required for full running capacity. The burning is done in a series of updraft, cased kilns fired with natural gas (Plate VI B.) The source of the raw material is the high bank against which the plant is built. It consists of a mixture of very stiff clay or gumbo with silty clay and sand mixed together in irregular layers and pockets. The gumbo clay when used alone is very stiff and hard to work, it has a tendency to crack in drying, and has a very high air shrinkage. It burns to a steel hard body with fairly good red colour at cone 010, and softens at cone 1.

The silty clay is easy to work and dry, but makes a rather porous weak brick. These clays are so irregularly distributed in the bank that it is impossible to mine them separately. The gumbo clay remains in lumps after being passed through rolls and pug-mill, and does not break down and mix with the other clay so as to give a uniform body. The William clay crusher is said to overcome this difficulty, and to deliver the material to the pug-mill in a thoroughly pulverized condition. A machine that will pulverize wet gumbo as it comes from the bank will be a valuable addition to the clay workers equipment in the west. There will doubtless be many difficulties of a technical nature to deal with before this plant is running smoothly to full capacity.

Pottery Works at Medicine Hat.

The most important recent addition to the clay working industries at Medicine Hat is the works of the Medicine Hat Pottery company (Plate VII B). This plant is erected and equipped for the manufacture of stoneware goods. A large quantity of these articles were turned out during 1913. These consist of churns, butter crocks, milk pans, jugs, and jardinieres. The stoneware clay used at this plant is all brought by rail from the Spokane district in the state of Washington. Some attempts have been made to use the clays from Dunmore and Redcliff, but they all proved too impure, and too easily fusible, besides having very serious drying defects.

The ordinary Bristol and Albany slip glazes are used, but some experiments have been made with local clays for this purpose. The trials so far made show that a light brown or yellowish glaze can be obtained from a washed clay that occurs in the vicinity of the works.

This local clay is also used for making flower pots. It burns to a red-coloured, smooth body at a temperature of 1850 degrees F. The pottery company is searching for a clay in western Canada, which would meet their requirements, but so far they have not found a suitable material. They have not as yet tried the stoneware clays that occur in the Dirt hills in southern Saskatchewan, but it is probable that these clays will upon trial prove to be the best material in the region for their purpose.

EDMONTON FORMATION.

The numerous tests that have been made by the writer on the clays and shales of this formation, have failed to reveal any satisfactory material for use in the manufacture of clay products, except the shales at Entwistle, described in Memoir 25, page 49. Most of these clays are exceedingly plastic, with very high shrinkages, they burn to a red colour, and develop an objectionable white scum on the surface of the burned ware. Their most serious defect is cracking in drying, a difficulty not easily overcome even by using the dry-pressed process.

The clay beds of this formation are associated with lignite seams, sands, and soft sandstone. The irregularity in bedding and the lack of continuity in the various members of this formation have been alluded to in former reports.

Nevis.

The presence of white clay in the Edmonton formation was discovered early in the autumn of 1912 by Mr. J. O. Williams of Camrose, and the locality was visited by the writer during the following year. The white clay is exposed at intervals along the line of the Lacombe branch of the Canadian Pacific railway, between Alix and Nevis, the sample collected for testing being taken from the north half of sec. 15, tp. 39, range 22, W. 4th mer.

The clay is exposed at the base of a low escarpment and in some outstanding buttes (Plate VII A); the generalized section in the locality being as follows:

	Feet.
Surface gravel	1
Grey sandy clay	10
Dark brown clay	20
White shale	2 to 4
Grey shale	3

The white clay or shale (144) is quite hard, and rather massive in structure, breaking down into irregular lumps. It is sandy in texture when dry, but when ground and mixed with 22 per cent of water it becomes highly plastic and even sticky. Its drying shrinkage is 6 per cent, but its drying qualities are poor. It behaves as follows in burning:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0·0	14·0	
06	1·0	13·0	
03	2·3	9·4	
1	3·0	5·6	
3	3·7	5·6	
5	4·0	4·3	
10	Vitrified and slightly swollen.		
16	Softened.		

This material is not a fireclay, but it is by far the most refractory clay found up to the present in the Edmonton formation. Its poor drying qualities are against its use for any of the wet-moulded processes of clay working, but it might be used for cream-coloured or buff face brick when made up by the dry-pressed process. The deposit is not very accessible at this point as it carries too great an overburden of useless clay, but farther west nearer Nevis the white clay occurs nearer the surface. It also outcrops on the banks of Tail creek with a light overburden, and not far from the railway, but it does not appear to be in a bed much thicker than 4 feet at any point observed, although further prospecting may reveal a thicker deposit. The following chemical analysis of the white shale was made by Mr. Theo. H. Young of the Canadian Pacific laboratories at Winnipeg:

Silica	66·37
Alumina	26·62
Iron	1·28
Lime	0·42
Magnesia	trace
Alkalis	0·42
Sulphur trioxide	trace
Titanium	trace
Loss on ignition	5·15

The grey clay or shale which underlies the white shale is exceedingly plastic when ground and tempered with water. It cracks so badly in drying that even the small test pieces made from it could not be dried safely. Some dry-press bricklets made from it burned to a rich light buff colour, but were fire-checked.

On account of the heavy overburden, the thinness of the beds, and their defective drying qualities, these clays do not appear to have any economic value in the manufacture of clay wares.

The overlying grey and brown clays are very impure, possessing the exessive stickiness, high shrinkage, and poor drying qualities which unfits them for use. Some shallow test pits dug on the flat at the base of the escarpment have become filled with surface water and a yellowish paste or jelly like substance which appears to be bentonite or soap clay, described in Memoir 25, page 89.

The grey shale underlying the white clay contains a considerable amount of this material as it also forms a jelly after slaking in water. Silica in the colloidal form appears to be the jelly forming constituent and to cause the cracking in drying.

Castor.

Five small samples of different clays or shales from this locality were submitted for examination by the Coalbeck colliery. Four of these were hard and soft grey shales with rusty streaks, while one was of dark brown clay containing lignite particles. These are all highly plastic, stiff, pasty material when wet, and had bad working qualities.

All of the small test pieces made with the grey shales cracked badly in drying, even when mixed with 50 per cent of sand. They burn to a red colour, and are fused at cone 3. They would not be suitable for the manufacture of clay products unless treated in some manner to destroy the stickiness and tendency to crack. After treatment they might be used for the manufacture of common or dry-pressed brick or for fireproofing, but their softening point is too low to allow of their use for vitrified wares.

The test pieces made with the brown clay did not crack in drying. It burned to a good hard red body at cone 06, but it must be fired slowly or it will bloat, on account of the carbon it contains. This clay was fused at cone 5. Its drying qualities could not be tested, as the sample submitted was too small. Small test pieces will sometimes dry intact, when full sized ones made from the same clay will crack, owing to the thicker mass of clay that has to be dried.

TERTIARY FORMATION.

This overlies the Edmonton formation, and forms a broad belt extending from somewhat north of the Grand Trunk Pacific railway, west of Edmonton, southward almost to the International Boundary. This formation consists of alternating beds of shale and sandstones, but outcrops are rather scarce as much of the area it underlies is covered by drift materials.

The shales of this formation are worked extensively for the manufacture of dry-pressed and wire-cut bricks in the Calgary district. A description of occurrences of shales with the results of tests at several localities in Alberta, is given in Memoir 24. Further investigation has resulted in additional data that follow.

Didsbury.

Various beds of shale, and one thin lignite seam, interbedded with sandstone layers, are exposed at intervals in the valleys of small tributaries of Rosebud creek, in this locality. An examination of these was made on the property of Mr. Wm. Hunsperger, which lies about half a mile south of the Canadian

Pacific Railway station. At this point a small stream has cut down a trench or coulée in the level upland, to a depth of 40 feet or more. The slopes of the coulée are mostly grassy or wooded so that it is impossible to get complete sections, without doing considerable stripping. As far as could be observed, beds of soft sandstone appear to constitute the greater part of the section. There are some fairly thick beds of shale overlying the sandstone, and other shale beds occur lower down in the bank which are covered with too great a thickness of stone to be accessible. The sections are very irregular, however, but it is possible that in some places the shale beds may thicken and form a workable deposit without having to mine too much sandstone.

One sample (148) taken from the top of the bank, represents an average of about 6 feet of dark grey shales. When finely ground and mixed with water, this shale had good plasticity, and working qualities. The drying shrinkage was 5 per cent, and the drying qualities are fairly good. It gave the following results on burning

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0·0	14·7	red
06	0·0	14·0	red
03	2·4	9·2	dark red
1	6·0	0·0	brown
3	begins to soften		

This shale would work well by the stiff-mud process, and produce an excellent building brick at cone 06. If burned to a higher temperature it would yield a dense brick suitable for sewer linings. It also appears to be plastic enough to be used for the manufacture of fireproofing or hollow building blocks. When made up by the dry-pressed process and burned to cone 3, it makes a very good red face brick, with a strong dense body.

There are some layers of soft sandstone underlying this shale, a foot or so of which might be included in working and ground up with the shale, as the latter is sufficiently plastic to hold more sand.

Another bed of shale, about 20 feet lower down in the bank, was about 3 feet in thickness and overlaid a thin seam of lignite.

This shale (149) grinds easily, and requires 21 per cent of water for tempering. Its plasticity and working qualities are very good. It has good drying qualities, the drying shrinkage being 5 per cent.

It behaved as follows in burning:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0·0	25	salmon
06	0·0	24	cream
03	0·3	21	cream
3	begins to soften		

This shale contains enough finely divided lime to cause it to burn to a cream colour, and porous body. It will make a good strong building brick when burned to cone 03 or higher.

An exceedingly fine face brick can be made by using a mixture of equal parts of this shale and the red-burning one just described. Some sample bricklets made of this mixture by the dry-press process and burned to cone 01, had an absorption of 16 per cent and were steel hard. The speckled colour of this mixture when burned was extremely effective. Rough-faced brick of various tones of colour can be made by the stiff-mud process from these shales.

Innisfail.

A thick covering of drift material almost completely conceals the character of the underlying bedrock in this vicinity. About 4 miles west of Innisfail, an outcrop of shale, about 15 feet thick, occurs on the south bank of the Red Deer river near the highway bridge. This shale is highly plastic and works well and burns to a bright red colour and dense body at cone 06, fusing about cone 4. It is a good brick or fireproofing shale, but has no commercial value owing to its location.

Macleod.

The stratified, stoneless, Pleistocene, brick clay appears to be absent in the immediate vicinity of the town of Macleod, the district being underlain by a thick deposit of boulder clay or by gravels. These superficial deposits effectually conceal the bedrock for the most part, as only one outcrop was seen during an examination of quite a large area. This consisted of a series of shale beds exposed on the south bank of the Oldman river, near the city stone-crushing plant in the town. The section as given below, shows the varied character of the shales in this district. It is measured from the top of the bank to the rivers edge.

	Feet	*Inches*
Coarse river gravels..................	14	
Dark grey, plastic shale................	1	6
Shaly sandstone......................	2	
Mottled purple and green shale, very plastic..........................	3	
Grey, sandy shale.....................	2	
Dark grey, soft, crumbling, plastic shale...	3	
Mottled green and purple shale, with lime nodules.........................	2	6
Soft sandstone and sandy shale, with gypsum..........................	4	

The heavy overburden of gravels renders this material inaccessible, otherwise all the shale beds above the one containing the limestone nodules, might be worked for brick or fireproofing.

Porcupine Hills.

The eastern escarpment of the Porcupine hills rises rather abruptly from the plains about 10 miles west of Macleod (Plate VIII A). No bedrock was observed on this plain (Plate VIII B) as it is covered by either stony clay or gravels, almost to the foot of the hills. The upper part of the escarpment appears to be composed mostly of sandstone, the harder beds of which project in horizontal ledges, while the lower slopes are chiefly soft grey or reddish shales. Some small detached knolls near the junction of the plain and the hills are made up of banded pink, yellow, or grey clays, which outcrop in large patches.

An average sample of these vari-coloured clays was collected for testing, from the northeast quarter of sec. 17, tp. 9, range 27, W. 4th mer. This clay (150) requires 23 per cent of water for tempering, it is very plastic, and has fairly good working properties. The shrinkage on drying is 6 per cent, but its drying qualities are poor. It burns to a dense red body with buff specks at cone 03. On account of its poor drying qualities this clay is better adapted for use by the dry-press process, and will make a very fair light red face brick if burned to about 2000 degrees F. It is not adapted for the manufacture of vitrified wares as the fusing point of the clay at cone 3 is too low. This clay contains lime in coarse particles, and underburned products made from it will distintegrate on exposure to the weather.

A thick bed of plastic grey shale occurs higher up the slope of the hill, underlying a hard sandstone ledge. This shale was sampled in the hope that it might be a fireclay. It proved on testing to be a rather easily fusible, red-burning material, melting to a slag at cone 5.

The clays and shales in this locality are too far from transportation facilities at present to be of economic value.

BENTON SHALE.

Blairmore.

There is an abundance of dark grey, or brownish Cretaceous shales of the Benton formation in this locality. The best exposures are seen near the mouth of York creek, which cuts through these shales at right angles to the strike of the beds.

Four samples from different parts of these shales were collected at this point by W. W. Leach, of the Geological Survey. These four samples are so much alike in all respects that the tests for one of them will serve for illustration of the whole series.

The shales were ground to pass an 18 mesh sieve, and tempered with 17 per cent of water. The wet shale was very gritty to the feel, and its plasticity was so feeble that it was difficult to mould into shape. It can be dried as fast as desired; the shrinkage on drying is only 3 per cent. The burning tests are as follows:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	0·8	11·0	light red
06	0·8	10·0	light red
03	2·5	7·5	dark red
1	2·5	7·0	dark red
3	3·0	6·0	dark red
5	swells		

This shale contains a small amount of carbonaceous matter which will give trouble in burning unless fired very slowly during the oxidation stage. It takes a very bright uniform salt glaze at cone 4, so that it would probablt be suitable for the manufacture of sewer-pipe if the plasticity of the material could be improved. It is doubtful, however, if this could be done, unless by the addition of some highly plastic clay. Owing to its lack of plasticity this shale is best adapted for use by the dry-pressed process. It will make a good red face brick by this method if burned to about cone 02.

Sheep Creek.

A sample of light grey clay from the vicinity of Sheep creek was sent to the laboratory for examination. The locality given was tp. 21, range 3, W. 5th mer., which is rather vague, and no statement was sent regarding the extent of the deposit. The material is a light grey soft shale, with the appearance of a weathered talcose schist. When ground and mixed with 24 per cent of water, it was very plastic, rather smooth to the feel, but stiff and hard to work. Its drying shrinkage was 8 per cent; the drying qualities do not appear to be very good, but the test pieces did not crack. It seems to have the necessary refractoriness for the manufacture of sewer-pipe, but the shrinkage is rather too high. Its tendency to crack would also be against its use for this purpose. If a certain quantity of the shale were calcined and added to the raw clay, both these defects could probably be overcome. The burning tests are as follows:

Cone.	Fire shrinkage. %	Absorption. %	Colour.
010	1·6	12·0	buff
06	2·0	10·0	buff
03	3·0	6·2	buff
3	4·0	4·8	grey
5	4·0	3·5	grey
11	fused		

When made up by the dry-pressed process and burned to cone 1, a face brick of fine buff colour and dense steel-hard body is produced. This material seems well adapted for this purpose.

CRETACEOUS.

Athabaska River.

The following notes refer to some samples of clay collected by Mr. Sidney Ells, who examined the tar sand deposits in northern Alberta during the summer of 1913.

It should be noted that the clays secured were merely small samples from surface outcrops. During the warm weather, bitumen and lighter oils seep out of the overlying tar sands and run down more or less over the underlying strata. It is, therefore, possible that the body of these clays may be free from the contamination that exists on the outcrops from this cause. An effort will be made to secure larger and more representative samples of these clays, during further exploration.

No. 187. This is a dark grey, almost black clay in a bed 12 to 15 feet thick, underlying bituminous sand on Moose river.

This clay is very plastic, fine grained, and smooth, it is rather stiff in working but not sticky. Dries very slowly with a drying shrinkage of 6·5 per cent. This clay contains so much asphaltic carbon that it is very hard to burn test pieces without swelling. The density of body due to the extreme fineness of grain of the material renders the burning-off of the carbon, during the oxidation stage, a tedious process. It burns to a light red colour at the lower temperatures and a buff or grey colour at higher heat. It vitrifies at cone 5, and fuses at the softening point of cone 20.

No. 188. This is a dark grey clay, exceedingly plastic and smooth, smelling strongly of asphalt when damp, collected on east bank of Athabaska river, about one-third of a mile above Fort McMurray. It burns to a light red colour at low temperatures, becoming grey when heated to about cone 5, and is fused at cone 16. Owing to its fineness of grain, and carbon content, this clay is very hard to burn without becoming bloated.

No. 190. This is a light grey, fine-grained clay from south bank of Muskeg river at base of bituminous sand; the deposit is at least 10 feet thick. It is a very fine-grained, plastic clay, which works up like a modelling clay. It burns to a steel hard cream body at cone 3, and does not begin to soften until the softening point of cone 27 is reached. This is the most refractory material at present known in the province of Alberta.

No. 191. This is a dark grey, very smooth, plastic clay, interbedded between bituminous sand and Devonian limestone on Moose river. It burns to a salmon-coloured dense body at cone 3, with a rather high shrinkage, and fuses at cone 18.

These four samples of clay are very similar in their physical characteristics, and appear to occur in the same geological horizon, viz., underlying the Tar Sands. They are very fine-grained sediments, comparatively low in fluxing impurities, and are more refractory than any of the Cretaceous clays in southern Alberta, No. 191 being almost in the fireclay group.

The samples were too small in size to allow of any complete determinations regarding their working and drying qualities, but they appear to be free from the defects so common in Cretaceous clays farther south.

These clays are of the stoneware type, being very plastic and smooth, burning to a dense light coloured body at cone 5, and capable of retaining their shape when heated to a considerably higher temperature. Their most serious defect is the presence of asphaltic carbon, which renders the safe burning of wares made from them a difficult process. Nos. 190 and 191 appear to be free from this impurity. Owing to their position under heavy overburdens, and their remoteness from transportation facilities, it is doubtful if these clays can be utilized, at least for some time to come.

CHAPTER IV.

DRYING OF CLAYS.

The most serious difficulty encountered during the process of manufacture of clay wares in the Great Plains region of western Canada, occurs in the drying stage.

The defective drying qualities of many of the clays is undoubtedly a great obstacle to the development of the clay products industry, and several failures that have been already made are due to this cause alone. The writer has been working on methods of overcoming the tendency towards cracking for some time. The results published in Memoir 25, Chapter VII, contain an account of all the experimental work done up to that time. Some results of further work done along this line of investigation are given in this chapter for the first time. The methods usually adopted in dealing with this trouble are briefly as follows.

ADDITION OF NON-PLASTIC INGREDIENTS.

More than 50 per cent of sand is usuallv required to overcome cracking in drying, with these clays. This amount of sand does not always improve the working qualities of the clay, and the burned body with such a mixture is too weak to be of any practical value.

By substituting calcined clay for sand a better burned body is produced, but the amount required to overcome the cracking is usually so large as to render the body too gritty, and unworkable in clay machinery.

THE PREHEATING METHOD.

This method seems to give good results. It consists in heating the raw clay in a rotary kiln to a temperature from 400 degrees to 600 degrees C., or a temperature that stops short of destroying all plasticity, which varies for different clays. This preliminary heating destroys the adhesive, pasty qualities of the clay, causes it to become somewhat granular in texture, and much easier to work and dry than in the raw state. This process seems to have been tried at a clay plant in Edmonton, and it is stated that the results were successful. The expense of the preheating treatment is the chief obstacle to its use.

EFFECT OF CHEMICAL COAGULANTS.

Highly plastic clays are affected in a marked degree by the addition of chemicals that coagulate and render them denser. A less amount of water is required to produce plasticity by the use of small amounts of these substances, hence the shrinkage is reduced and the drying hastened. Various coagulants were used in the investigation, including carbonate of soda, barium hydrate, hydrochloric acid; but the clays were only slightly affected by these chemicals and none of their objectionable features were overcome.

The only material of this class which proved of assistance was common salt. About 1 or 2 per cent of salt had the effect of keeping the surface of the moulded pieces moist while the body was drying. The drying qualities were improved by its use, but the working qualities were not.

EFFECT OF CAUSTIC LIME.

It has long been observed by the writer during the testing of a large number of western clays that the more calcareous ones generally gave less trouble in drying than the non-calcareous clays.

A series of tests were consequently made to determine the effect of the addition of various percentages of lime to those clays that cracked in drying. The only form in which lime was effective for this purpose was in the caustic state, generally known as quicklime.

Many of the clays described in this report are exceedingly plastic, and stiff and sticky when wet, so that they are difficult to work in any form of clay working machinery. These bad working qualities, when accompanied by defective drying, render them very undesirable for the manufacture of clay products.

The addition of 1 to 3 per cent of quicklime to these clays gives immediate relief, by destroying the stickiness, and causing an extraordinary difference in the ease with which they can be worked up. An excess of quicklime will make the wet body actually short and crumbling so that it would be liable to tear in moulding. The quantity of water required for tempering the clay is increased by the use of quicklime.

The effect of caustic lime on drying is even more pronounced than on the working qualities of the clay. Small test pieces that cracked badly when drying in a room, could be dried intact when exposed to warm sun and wind, when a small percentage of it was added. The quicklime should be finely ground and thoroughly mixed with the clay at least 24 hours before using for moulding.

The effect of caustic lime on the burned body is the weak point of the mixture. It causes a white scum on the surface of the burned ware, and weakens the body unless burned to a high temperature.

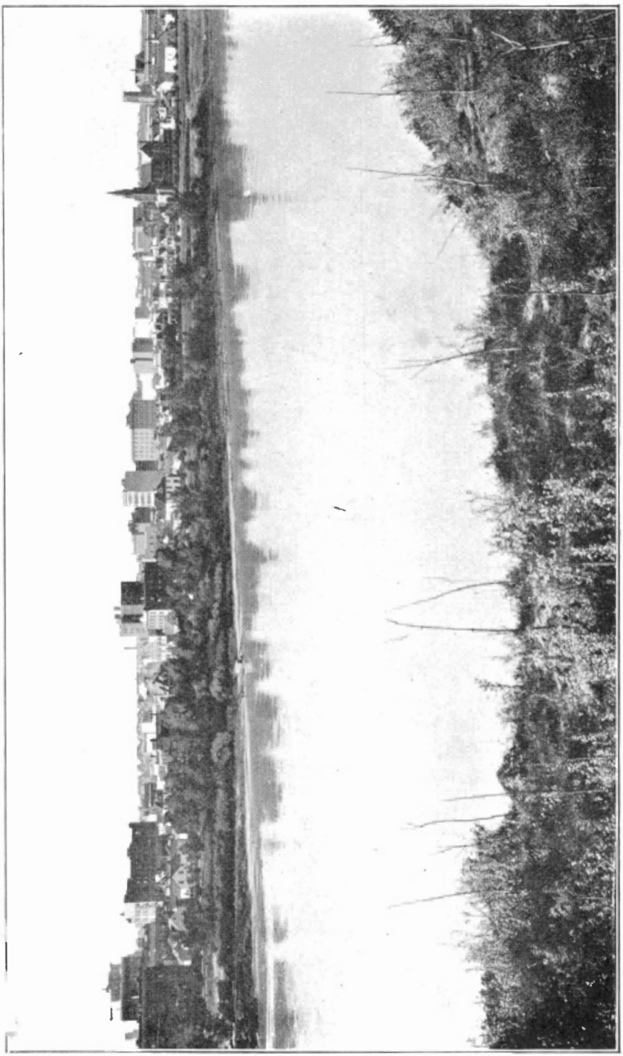
The experiments with this ingredient have not been carried far enough yet to make a full report on its effect on the various clays.

Clayworkers as a rule avoid lime if possible, as it is a detriment, especially when present in coarse particles. Its use in connexion with these troublesome clays is only advocated as a last resort, when other remedies have failed. One sample when burned showed no effect of the quicklime, except a somewhat lighter colour.

EXPLANATION OF PLATE I.

The Saskatchewan river at Saskatoon.

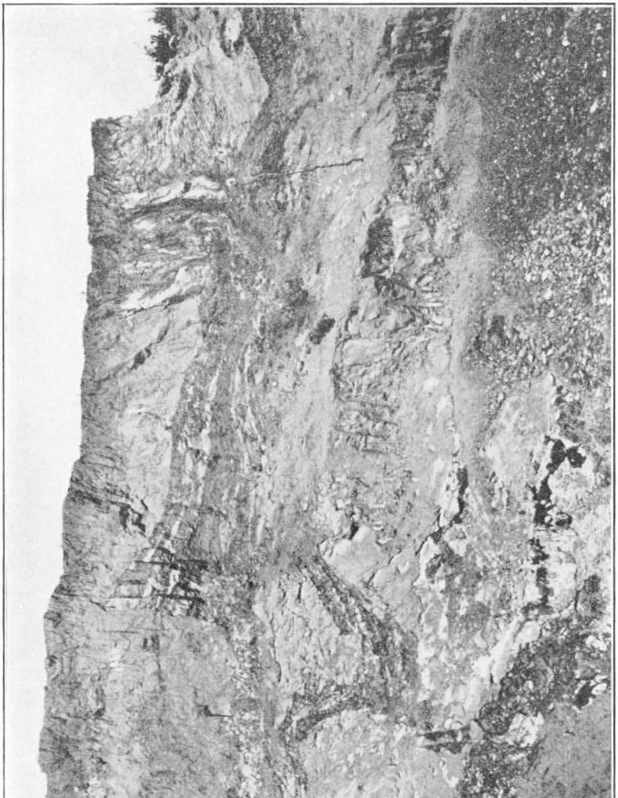
Plate I.



EXPLANATION OF PLATE II.

Section of Pleistocene clay at Elliott's brick-yard, Saskatoon.

PLATE II.



EXPLANATION OF PLATE III.

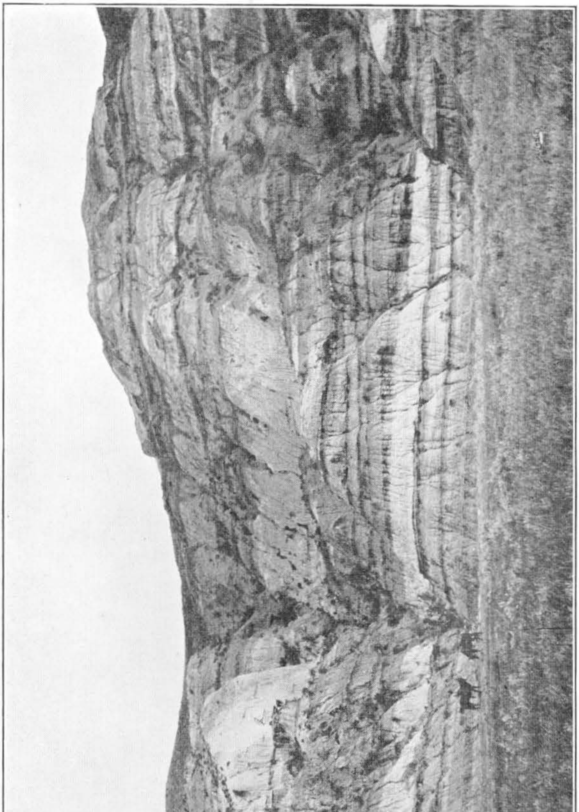
Stratified, stoneless, Pleistocene clay in pit of Canadian Clay Products Co., Floral, Saskatchewan.

PLATE III.

EXPLANATION OF PLATE IV.

Typical exposure of clay beds and lignite seams in Big Muddy River valley, Saskatchewan.

PLATE IV.



EXPLANATION OF PLATE V.

A. Brick plant and clay pit, Innisfail Brick Co., at Innisfail, Alta.

B. Cutting in stratified Pleistocene clay, Canadian Northern railway, near Bullocksville, Alberta.

PLATE V.

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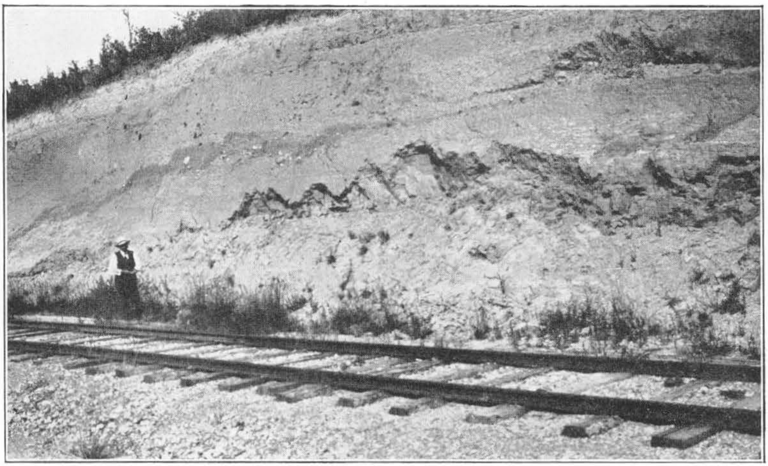

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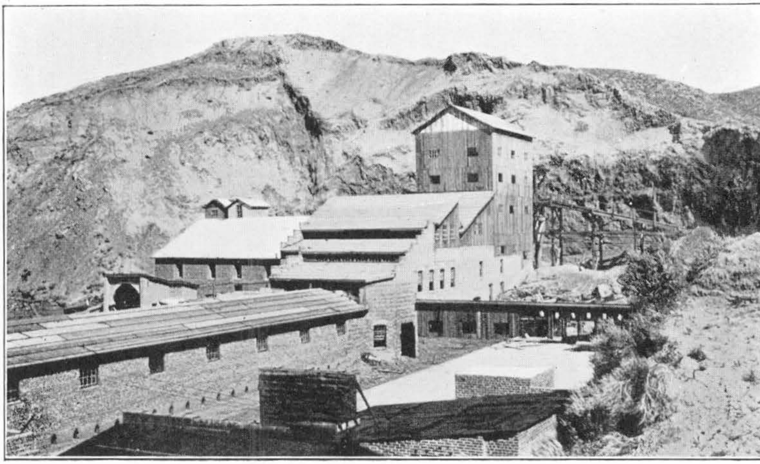
EXPLANATION OF PLATE VI.

A. Plant and clay bank of the Medicine Hat Brick company, Medicine Hat, Alberta.

B. Updraft case kilns, for burning common brick with natural gas at works of Medicine Hat Brick company.

PLATE VI.



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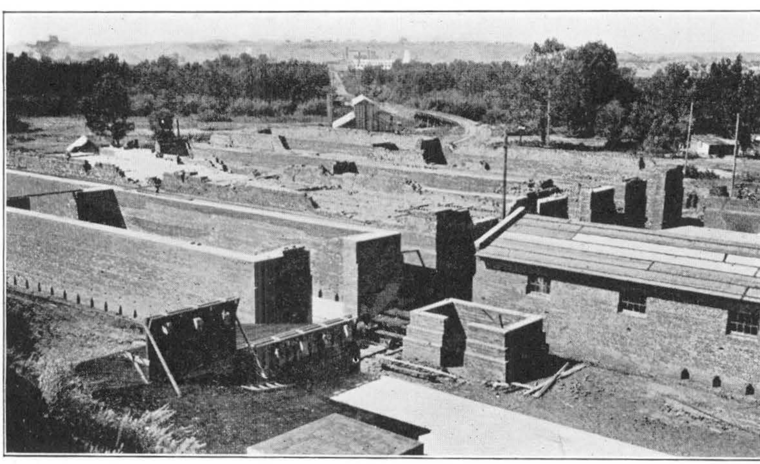

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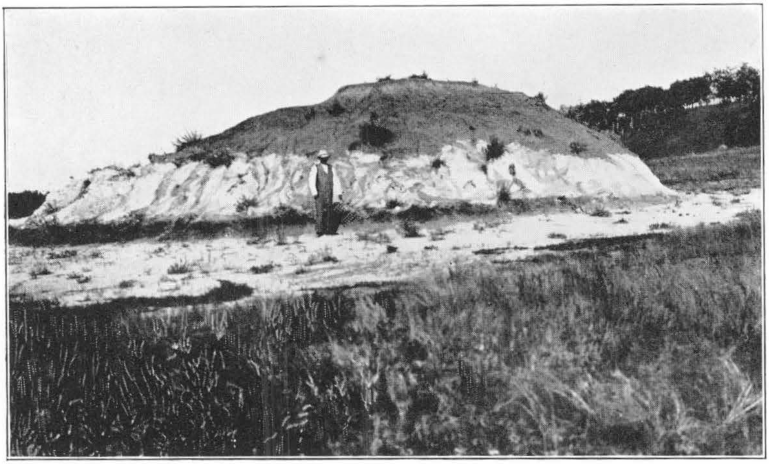
EXPLANATION OF PLATE VII.

A. White shale deposits in Edmonton formation, near Nevis, Alberta.

B. Plant of the Medicine Hat Pottery company, Medicine Hat, Alberta

PLATE VII.



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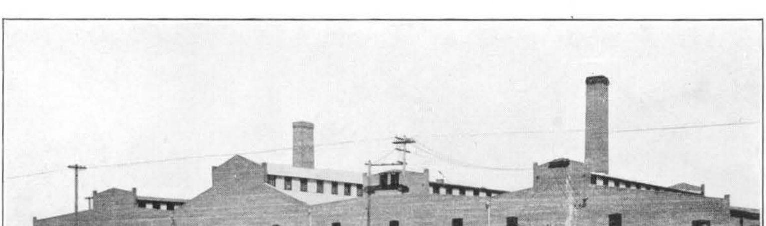

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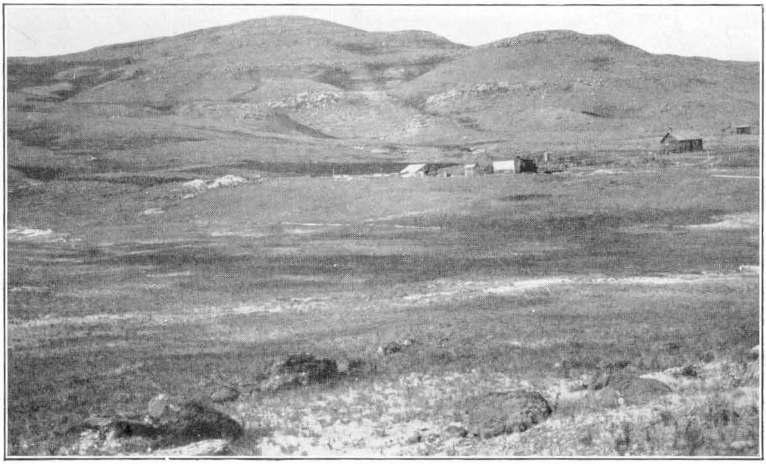
Explanation of Plate VIII.

A. Shale and sandstone beds in the eastern escarpment of the Porcupine hills, southern Alberta.

B. View looking eastward towards Macleod, across drift-covered plain, from Porcupine hills, southern Alberta.

PLATE VIII.



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LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, Province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries, assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B. C.—by D. D. Cairnes.

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