CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MINES BRANCH

OTTAWA

PRELIMINARY REPORT ON COATED LIGHTWEIGHT CONCRETE AGGREGATE FROM CANADIAN CLAYS AND SHALES

PART 1

ALBERTA

by

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Memorandum Series No. 117

February, 1952.

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PREFACE

In 1949 the Mines Branch began an investigation into Canadian sources of clay and shale raw materials suitable for the production of light-weight aggregates. This report contains the results of test work on samples from what are considered the most important known deposits within a marketable distance of well populated areas. Most of these samples were collected by the Branch during the summer of 1950 while others were submitted by individuals or companies. The samples collected weighed from 5 to 10 pounds and were taken by trenching so as to represent a true average of the deposit. Laboratory tests were conducted during the winter of 1950-51.

The aim of the laboratory work has been to produce the highest grade of aggregate, namely a coated aggregate, at the lowest cost by using the raw materials in their natural state. In view of the number of samples covered and the limited amounts of each, no work has been done on the suitability of the materials for the production of sinter aggregates either in the rotary kiln or sintering machine.

It should be noted, however, that many of the materials classed in this report as being unsuited for coated aggregate manufacture might be found very satisfactory for the production of sinter aggregate. For anyone considering such production the work covered in this report on raw materials for coated aggregate manufacture will at least eliminate the decidely unfavourable materials and will indicate those upon which further work should be done.

The Branch wishes to thank A.S. Dawson and W.G. Cowie of the Industrial Development Department, Canadian Pacific Railway Company, for submitting numerous samples of clays and shales that helped fill in gaps in the area surveyed. Reports and maps of the Geological Survey of Canada were of great assistance in locating outcrops.

John Convey,
Director, Mines Branch.

COATED LIGHTWEIGHT CONCRETE AGGREGATE

FROM CANADIAN CLAYS AND SHALES

PART I

ALBERTA

INTRODUCTION

Definition of Lightweight Aggregate

A lightweight aggregate may be defined as an aggregation of fine and coarse particles of a material which because of its light weight, strength, low absorption, and chemical stability can be mixed with cement to form a concrete of pre-determined characteristics. Coated lightweight aggregate has a thin, hard, smooth, outer shell or coat which gives the aggregate improved properties of high strength, low absorption, and good workability.

Types of Clay and Shale Lightweight Aggregate

Two distinct types of lightweight aggregate are made from clays and shales namely, coated type aggregate, and sinter type aggregate.

The first type is made by rapid firing in a rotary kiln. Gases released from within the clay or shale during the pyroplastic condition cause it to expand into light, cellular particles. The particles are usually well rounded due partly to the bloating action and partly to the tumbling taking place in the kiln. The quantity and quality of the fluxes in the shale allow this expansion or bloating to take place at a temperature below that at which the particles become sticky so that the product is discharged from the kiln in individual, coated particles. An ideally coated aggregate requires no crushing after firing to supply the required grade sizes.

Sinter type aggregate may be made in either the rotary kiln or sintering machine. If produced in the rotary kiln the process differs from that for coated aggregate in that the product is crushed to supply the required grade sizes. Due to the quantity and quality of the fluxes present this material cannot be fired with sufficient expansion below the temperature at which sticking occurs, so that the individual particles agglomerate and are discharged as clinker. The sinter aggregate produced on the sintering machine, except for being harsher, is similar to the sinter product from the rotary kiln. The raw material for the sintering machine process is finely ground and mixed with a pulverized fuel, pelletized, placed on a travelling grate, and ignited. A lightweight product is formed by bloating or sintering or by a combination of both depending upon the raw material. The sintering machine type product may be made from a greater variety of raw materials than the rotary kiln sinter and coated types.

Desirable Properties of a Lightweight Aggregate

The raw material selected for the production of a lightweight aggregate must be capable of giving a product possessing the following desirable properties:

(a) High Strength to Weight Ratio

The product must be light to effect a worthwhile saving in weight and at the same time be strong enough to meet strength specifications. Variations in both the strength and weight may be effected by modifying the processing technique. As the strength of a product is increased, the weight is also increased and vice versa. Because of their strong shell and spherical nature, coated lightweight aggregate particles tend to give a product with a higher strength to weight ratio than other types. The actual maximum weights specified for a properly graded aggregate under A.S.T.M. specifications, designation C130-42 are 75 lb./cu. ft. for the fine aggregate and 55 lb./cu. ft. for the coarse aggregate.

(b) Good Workability

The smooth, spherical nature of coated clay and shale aggregate particles promotes good workability whereas aggregate particles with sharp corners make a harsh concrete mix that is difficult to work around reinforcing bars, tending to give a honeycomb structure.

(c) Low Absorption

An aggregate with a high water absorption, unless it has been pre-soaked, tends to dehydrate the cement which has a harmful effect on the setting of the concrete. Coated aggregates generally have a lower absorption than other aggregates because of the coating covering the cellular interior.

(d) Uniform Size Gradation

The product must be composed of aggregate particles of a range of sizes with sufficient fine material to permit working the mix around forms and reinforcing bars. The grading prescribed may be referred to under A.S.T.M. specifications, designation C130-42.

(e) Chemical Inertness

A lightweight aggregate should not contain chemical impurities which might react with the cement or reinforcing materials with deleterious effects.

TEST METHODS

The equipment used for the laboratory evaluation of clays and shales for lightweight aggregate consisted of a small jaw crusher, screens, a gas-fired stationary furnace (capable of up to 2700°F), a drying oven, a 5" x 5' gas-fired rotary kiln, a bulk density container, a balance sensitive to one gram, and crushing strength apparatus.

Preparatory to testing, all samples were reduced in size to $-\frac{1}{2}" + \frac{1}{4}"$. Samples that were not coarse enough or were too soft to stand crushing were pelletized in a small cement mixer, dried, and screened to the above size range. Because of the shortness of the rotary kiln, all samples were dried overnight in an oven maintained at 100°C to drive off the mechanically held moisture and thus prevent decrepitation when subjected to rapid heat.

Stationary Furnace Tests

Small amounts of each sample were tested first in the stationary furnace at various temperatures and heating times. These tests facilitated the elimination of materials obviously not suited for coated aggregate manufacture and the selection of the most promising ones for testing in the rotary kiln.

By firing the materials at various retention times and temperatures it is possible to predict the relative length of vitrification range of each material and to observe the relative amount of bloating. If a material shows little surface fusion with a dull appearance when well bloated, indications are favourable for trial in the rotary kiln. On the other hand if, on increasing the temperature and firing time, the material is not bloated until the surface shows a high degree of fusion (glassy appearance) indications are that it has a short vitrification range, and will give sticking and agglomerating trouble in the rotary kiln. Materials with a very narrow vitrification range are thus eliminated from further testing but materials having intermediate properties in this respect must be tested in the rotary kiln before any conclusions can be drawn.

Stationary furnace tests permit the screening out of materials that are poor bloaters and those that are, for economical reasons, too refractory. For the purposes of this investigation all materials that failed to show any bloating when fired in the stationary furnace at 2400°F for five minutes, were classed as too refractory.

These tests also facilitate the elimination of materials that are extremely non-uniform in composition. Many materials, especially those laid down under shallow water conditions contain varying amounts of the fluxes or refractory constituents. In coal mine shales, a frequent cause of non-uniformity is the varying amounts of free carbon. Depending upon their extent these variations may mean the elimination of the material as a possible raw material.

Upon completion of the stationary furnace tests, the materials selected for the rotary kiln tests were those that had good bloating properties with a reasonably good vitrification range, were not too refractory, and showed reasonable uniformity.

<u>Rotary Kiln Tests</u>

The selected dried materials were processed in a 5" x 5' gas-fired, rotary kiln. Although the kiln had variable pitch and speed, all materials were processed under the same retention time conditions to give a total retention time of about six minutes. The temperature for each run was kept as close as possible to the maximum temperature permissible for each material without having agglomeration of the charge. In general, this is the temperature at which a commercial kiln producing coated aggregate would operate. It is possible to produce the same result at a lower temperature with an increased retention time but only at a great sacrifice in the volume of material handled.

It should not be assumed that the products made in the 5" X 5' rotary kiln in this investigation are the best obtainable. In view of the number of samples covered and the limited amount of each it was impossible to experiment with each sample to determine the best operating conditions. The small scale rotary kiln tests carried on in this investigation merely indicated which materials have the best possibilities for commercial rotary kiln coated aggregate.

The determining factor in whether a good bloating material is suited for coated aggregate manufacture or not is the degree of sticking and agglomeration of the particles when bloating. This property can be determined quite satisfactorily in the small kiln.

As a result of the stationary furnace and rotary kiln tests the materials were classified into five groups which are shown in a summary table for the province in Figure 4. These classifications are as follows:

1. Materials considered suitable for coated aggregate production.
2. Materials which are good bloaters but which are not considered suitable for coated aggregate production because of their relatively narrow vitrification ranges and resultant sticking and agglomerating characteristics.

3. Materials which are poor bloaters.

4. Materials which are too refractory.

5. Materials which are non-uniform and which are a combination of two or more of the above classifications.

For anyone interested in the production of sinter aggregate in the rotary kiln the logical materials for experimental work, of those collected, would be those listed in groups 1 and 2 above. Since a high bloating material is not desirable for sintering machine treatment, the possible raw materials for this type of aggregate are those listed in group 3 above.

As for the materials classified in table form as having good possibilities for coated aggregate manufacture, it should be remembered that this classification is based only on the quality of product. Other facts that are of decided economic importance such as amount of material available, nearness to markets, and availability of fuel are discussed, when available, under the test results for each material.

It must also be kept in mind that this investigation is concerned only with the use of materials in their natural state. It is quite possible that chemical beneficiation would convert some of the unsuitable into suitable materials. Again, many materials classed as too non-uniform might prove quite suitable if finely ground and pelletized before firing, all of which of course, would increase the cost of production.

Determination of Physical Properties

Three physical properties of the aggregate were measured, namely the bulk density, the crushing strength, and the volume expansion.

The bulk density was determined in a machined metal container of 1/30 cubic foot capacity on the product crushed to -3/8 inch + 8-mesh. The standard jigging procedure as specified in A.S.T.M. designation C29-42 was followed. This size range (-3/8 inch + 8-mesh) approximates that specified in A.S.T.M. specifications, designation C130-42, and should have a bulk density value of less than 55 lb./cu. ft. to be acceptable.

The test used to determine the crushing strength, was patterned on that carried out in other laboratories. The apparatus consisted of a steel cylinder, 2 inches inside diameter, and 6 inches deep, into which the aggregate crushed to -3/8 inch + 8-mesh was poured without any tamping, to a depth of 4½ inches. A 1 31/32 inch diameter steel plunger applied the pressure to the aggregate in a Carver Hydraulic Press and the amount was noted to give a compaction of 1 inch. This was then converted to lb./sq. inch.

The true value of this test has not been determined. It should, however, provide a rough method of rating the various products but, to do so, it should be considered along with the weight of the product. Since the weight and strength vary directly, the crushing strength-to-weight ratio gives a better method of evaluating the various products.

The volume expansion of the product was measured simply by measuring the volume of the clay or shale feed before firing, and the product after firing, and by calculating the percentage increase. The volume expansion of a material affects the economy of the operation because, the higher the volume expansion, the less the amount of feed material required to give the same volume of product.

It should be kept in mind that the mere expansion of a clay or shale does not necessarily mean that it will make a good concrete aggregate. Considerable test work must be done on any one material to determine the maximum allowable expansion necessary to give a product of the required strength. Neither is there any substitute for actual concrete tests in evaluating the product.

RELATION OF CHEMICAL PROPERTIES TO THE BLOATING OF CLAYS AND SHALES

Review of Previous Work

T. E. Jackson[1] considered it possible that bloating of clays might be due to the evolution of oxygen as the ferric oxide passed into the ferrous oxide on combination with the silicates.

Orton and Staley[2] thought that if Jackson's theory were correct all bloating clays would contain ferric oxide and should, therefore, bloat at the same temperature. They found, however, that clays bloated at different temperatures, and moreover, that many clays which contained iron, did not bloat. They considered the cause of gas evolution to be chiefly the dissociation of sulphides and sulphates by silicic acid which becomes increasingly active as the temperature rises and appropriates the bases formerly combined with the sulphur. They considered that the sulphur came out of solution as sulphur dioxide and that this gas was responsible for the bloating. They also recognized that sulphur did not oxidize to sulphur dioxide and escape until after the carbon had been oxidized. In many cases, especially if the firing was rapid, by the time the carbon was oxidized the clay had become too dense to allow the sulphur dioxide to escape and bloating resulted. They treated bloating as an undesirable quality and concluded that it could be avoided by applying a deliberate and complete oxidation treatment while the clay remained porous to remove the carbon and sulphur.

Wilson[3] considered that the gases causing bloating when the clay or shale had reached the vitrified condition might consist of entrapped air, steam, sulphur dioxide and trioxide, carbon dioxide or monoxide, oxygen or hydrocarbons absorbed during firing. He treated bloating as an undesirable quality of some clays and shales, and observed that it took place to a greater degree in the fine-grained, dense materials. He divided the expansion caused by entrapped gases in a semiviscous body into two classes: bloating caused by improper oxidation due to insufficient heating time at temperatures below the vitrification period to allow the escape of gases chiefly formed from the carbon, sulphur and carbonates, and bloating due to gases formed during and above the vitrification temperature, the most common of which is sulphur dioxide or trioxide formed from the decomposition of calcium sulphate.

Bleininger and Montgomery[4] stated that if at any time the evolution of gaseous matter was rapid enough to produce pressure within the clay, then bloating was certain to take place, and a vesicular structure would be formed. They recognized that both the physical constitution of the clay, that is, compactness and fine grain, as well as the mode of shaping, were of as great, if not greater, importance than the amount of constituents present which form gases.

The United States Emergency Fleet Corporation[5] which developed lightweight aggregate during World War I for use in the construction of concrete ships found that the clay or shale should be rich in compounds of metallic oxides, carbon, sulphur, sodium, potassium, or other equivalent compounds, some of which, when the material is subjected to heat, will either act as a flux or give off gas.

Experiments by Jackson[6] showed that not all the sulphur was evolved at low temperatures but that complex compounds of sulphur, such as "ferrous sulpho-silicate" were formed. Jackson observed that sulphur is not retained at high temperatures without the presence of iron oxide in the clay. He believed that the bloating of clay was due to sulphur but only that sulphur retained at high temperatures in the complex compounds with iron and silica.

Sullivan, Austin and Rogers[7] when experimenting with making expanded clay building units found that, for most clays, best results were obtained when the kiln atmosphere was slightly on the reducing side. They also found that in general, high lime clays had a short bloating range and low lime clays, a longer one.

Austin, Nunes and Sullivan[8] heated various clays in a tube furnace and determined quantitatively the gases evolved during bloating. They also determined the effects on bloating of varying the heating rates, rate of air flow and the atmosphere. These investigators found that carbon dioxide, sulphur dioxide, and water were evolved at the bloating temperature. They believed that, since most carbonates decompose at low temperatures, the carbon dioxide was formed by the oxidation of the elemental carbon that remained in the clay by reduction of the ferric oxide. They suggested that the sulphur dioxide might be evolved from the decomposition of residual calcium or magnesium sulphate or intermediate compounds formed during the firing. The water evolved was considered to have come from some mineral other than clay as clay loses its crystal lattice structure at a temperature below the bloating temperature. In general, the evolution of gases from clays varied inversely with the rate of heating, and directly with the air flow. It was shown that good bloating took place in a nitrogen atmosphere which indicated that the oxidation must come from within the clay rather than from a reaction with the atmosphere.

Conley, Wilson and Klinefelter[9] made an extensive study of the availability of raw materials, methods for producing lightweight aggregates, and on causes of bloating. Their work indicated that various compounds of iron, alkali, and alkaline earths furnished the fluxes and gases necessary to bring about bloating. Using this assumption various admixtures of such compounds were added to non-bloaters and to poor bloaters with good results in some cases. They found that the results varied decidedly depending upon the clay to which the admix was made, and that each clay required a separate study. These authors attempted to correlate the bloating properties with chemical analyses, and from their work concluded that chemical analyses were only of partial value as they did not indicate the mineral form of the impurities. They observed that the mineral form of the impurities in the clay was the key to whether a clay or shale would bloat or not.

Charles M. Riley[10] stated the two conditions necessary for bloating as follows:

1. "Enough of the material must fuse to fill the pore spaces so that gases being formed will be trapped. The fused material must, of course, be viscous enough so that the gas does not escape by bubbling through it."

2. "Some mineral or combination of minerals must be present that will dissociate and liberate a gas at the time when the mass of clay has fused to a viscous melt."

He classified materials as bloaters and non-bloaters, and by plotting the chemical analyses on a composition diagram, was able to show that one condition of bloating could be defined i.e., the condition of proper viscosity at the bloating temperature. By adding pyrite, hematite, and dolomite to non-bloating mixtures, and by bringing the composition into the area defined on the composition diagram, Riley showed that these minerals could produce the gases necessary for bloating. It was also discovered that many igneous rocks whose compositions fell within the area of bloating on the composition diagram bloated well when ground and cast into briquettes. Riley supported the earlier contentions of Jackson(1) and thought the principal reason for bloating was the evolution of oxygen during the dissociation of Fe_2O_3. He also recognized that pyrite probably dissociated to give sulphur dioxide at high temperatures, and that dolomite probably formed intermediate compounds with the other constituents which retained some of the carbon dioxide until dissociating at the bloating temperature.

APPLICATION OF CHEMICAL ANALYSES TO PROBLEM OF PRODUCING COATED AGGREGATE

As this investigation was concerned only with the highest grade of aggregate i.e., coated aggregate, the differences between materials found suitable for coated aggregate production and those that were not, were of more interest than the differences between non-bloating and bloating clays. Many materials proved to be excellent bloaters yet were found to be unsuitable for coated aggregate because of their narrow vitrification ranges, and sticking and agglomerating qualities. Following stationary furnace and rotary kiln tests all materials tested were classified into one of the five groups previously mentioned under test methods.

Chemical analyses were secured of representative materials from each of the classifications except the non-uniform materials. Not included in the chemical analyses plotted are materials that had an excessively high combustible carbon content such as shown by many coal mine shales. Small amounts of carbon are probably most beneficial to bloating but excessive amounts mask the normal reactions taking place, and in the short heating time given the materials, only a thin surface coating of the particles showed any oxidation or bloating.

Some of the materials classed as poor bloaters would very probably be good bloaters, or found suitable for coated aggregate manufacture if the heating time were long enough to remove some of the excess carbon. The effect on bloating of removing excess carbon by prolonged preheating before subjecting the materials to bloating tests is illustrated in Figure I.

The decided improvement in the interior structure of the particles is not shown on the graph. The product formed without preheating a material high in combustible carbon expands by the swelling of the combustibles rather than bloating. With prolonged preheat treatment and removal of carbon a bloated cellular structure and a lighter product are developed. For these reasons shales high in combustible carbon were not considered as representative of their classification of poor bloaters.

The conditions necessary for a clay or shale to be suitable for the production of a coated aggregate are as follows:

1. The material must contain a compound that will dissociate, or form intermediate compounds that will dissociate with the formation of a gas or gases at a temperature at which the material is in the pyroplastic condition.

2. The material when in the pyroplastic condition must have a high viscosity so that the released gases will be trapped, and so that the surface tension of the particles is great enough to draw each particle mass together, and minimize agglomeration of the particles into a clinker.

3. The material must have a wide vitrification range to allow easy temperature control below the temperature at which sticking and agglomerating become excessive.

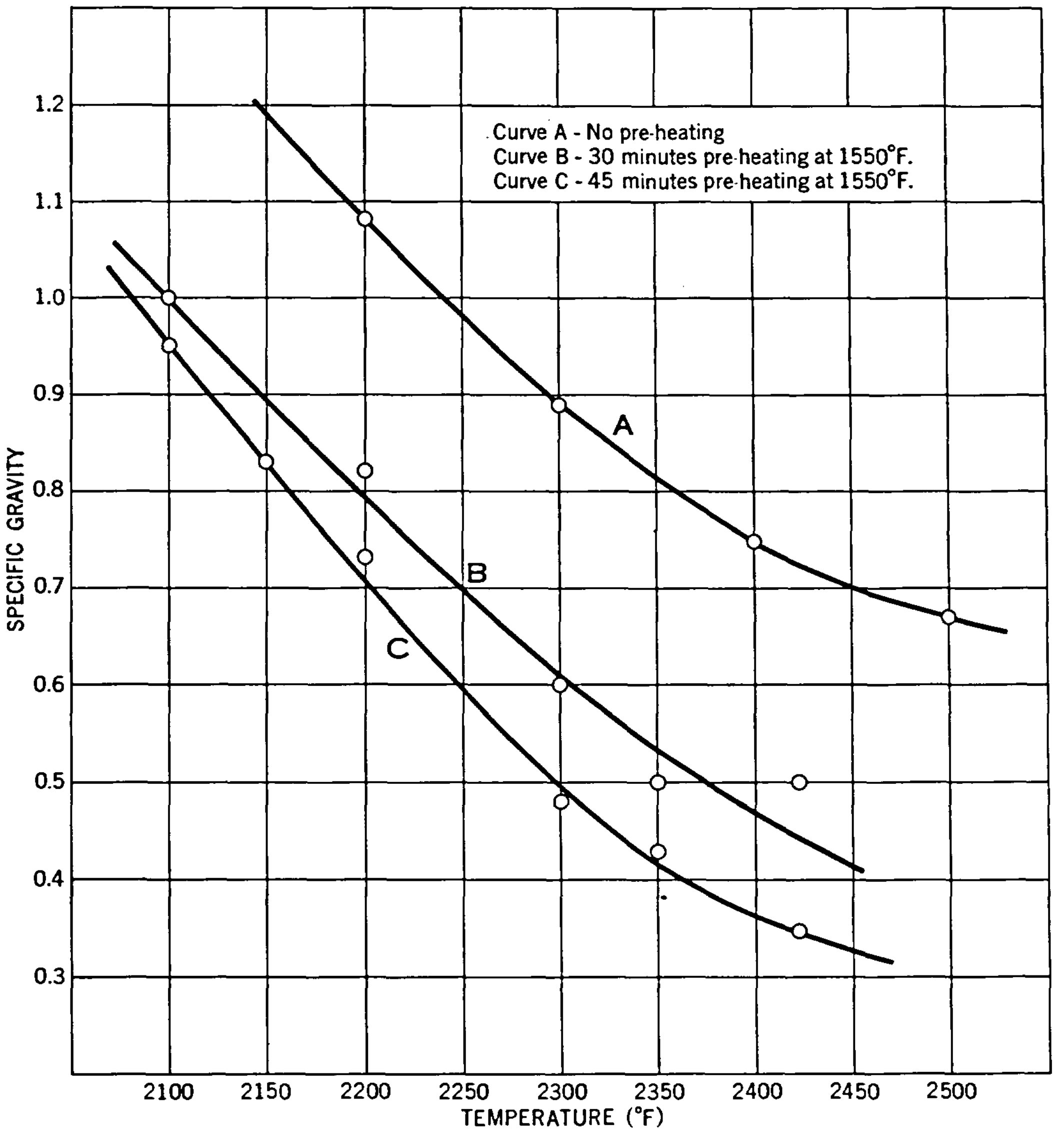

Figure 1 - Effect of preheating upon the specific gravity of bloated specimens of shale high in combustible carbon.

Previous work has shown that the chemical analysis of a material is of no value in determining whether the required gas-forming compound is present or not. However, in this investigation most materials showed some evidence of gas release or bloating with the exception of the refractory materials, a large number of which would show some bloating if the temperature were carried high enough. Other investigators have shown that a fraction of one per cent of a gas-forming compound is all that is required for good bloating of a clay or shale. In view of this it is probable that Condition 1 is not so important a determining factor as the conditions of high viscosity and wide vitrification range.

The composition diagram shown in Figure 2 with alumina, silica, and total fluxes at the corners shows that the viscosity condition requires the chemical composition of a clay or shale to be within a fairly well defined area. For this diagram the volatile material and minor constituents were neglected and the analyses recalculated on the basis of 100 per cent.

The vitrification range of a clay or shale for the purposes of lightweight aggregate manufacture covers the partially fused condition and is the range in temperature between the point of incipient fusion and the point at which the viscosity has decreased to impractical working conditions. The lower limit of the vitrification range is fixed by the temperatures at which the eutectic composition of the components begins to liquefy. The upper limit is fixed by the character and quantity of the fluxes present.

The fluxes containing sodium and potassium will give a wider vitrification range than those containing calcium and magnesium because their high viscosity retards their interaction with the surrounding clay grains. Fluxes containing calcium and magnesium have a low viscosity and shorten the

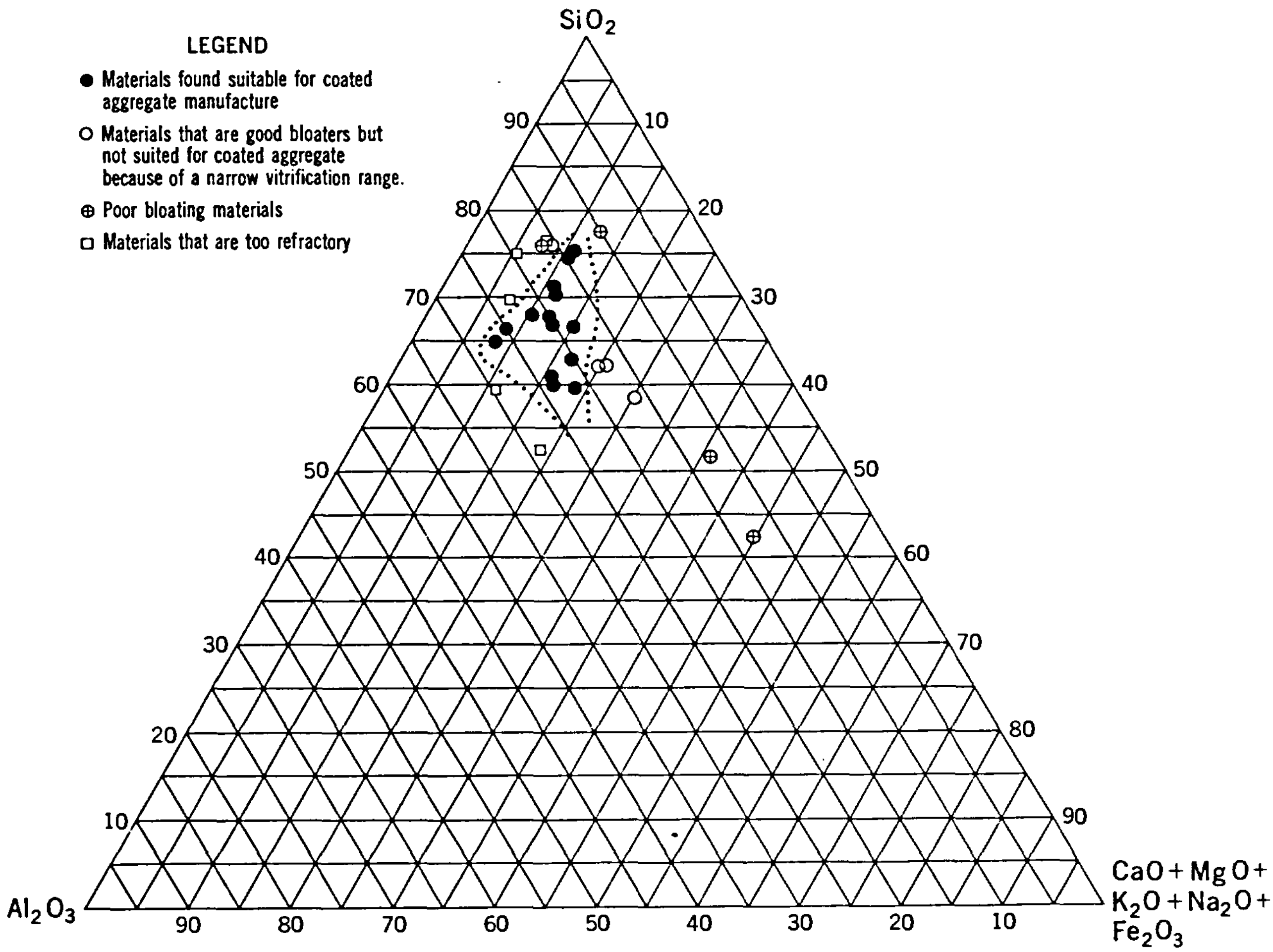

Figure 2 - Composition diagram of major oxides in clays and shales showing proportions required to produce coated aggregate. Dotted line represents approximate limits of materials suited for coated aggregate.

vitrification range. Ferric oxide is believed to be an intermediate flux. There seems reason to believe, therefore, that the vitrification range of a clay or shale should bear some relation to the proportions of the $K_2O + Na_2O$ and $CaO + MgO$ fluxes.

In Figure 3 the ratios of the $K_2O + Na_2O$ fluxes and $CaO + MgO$ fluxes have been plotted for the materials that had a wide vitrification range and were found suitable for making a coated aggregate and for the materials that were unsuitable and had too narrow a vitrification range. It is apparent from this diagram that a material, to have a wide enough vitrification range, should have an excess of the $K_2O + Na_2O$ fluxes over the $CaO + MgO$ fluxes. With only one exception all materials found suitable for making coated aggregate in this investigation had a value of greater than 1 for the ratio of $K_2O + Na_2O$ to $CaO + MgO$. The materials with too narrow a vitrification range had a value of less than 1.

The vitrification range of a clay or shale coated aggregate raw material has an important bearing on the size range of the feed for the rotary kiln. In most materials the extreme fine sizes start to agglomerate at a temperature below that sufficient to cause good bloating of the coarse sizes. However, if the vitrification range is wide this temperature may still be high enough to allow good bloating of the coarse sizes. Otherwise, the feed has to be separated in at least two size ranges, and each fired separately. In actual practice the vitrification range should be wide enough to allow bloating over a range of at least 50°F below the temperature at which sticking becomes excessive.

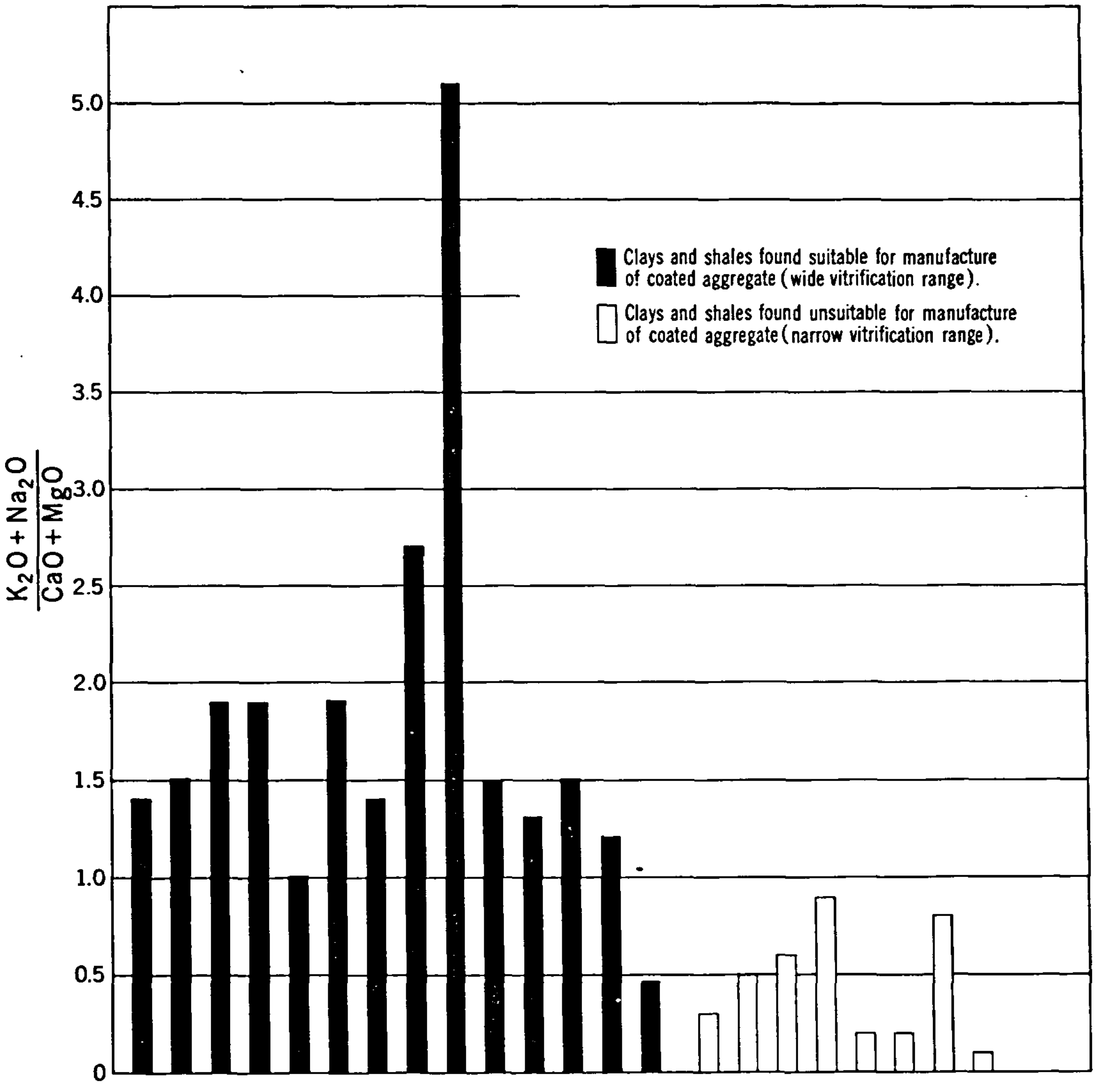

Figure 3 - Relationship of type of fluxes in clays and shales to width of vitrification range.

The chemical analysis of a clay or shale appears to be valuable for the defining of two conditions necessary for producing a coated aggregate namely, viscosity, and vitrification range but is of no known value in determining whether or not the required gas-forming compound is present. A material to be suitable for the production of coated lightweight aggregate should have proportions of silica, alumina, and total fluxes as defined in the composition diagram shown in Figure 2, and an excess of the $K_2O + Na_2O$ fluxes over the $CaO + MgO$ fluxes as illustrated in Figure 3.

Materials having good possibilities for coated aggregate production		Materials that are good bloaters but are not considered suitable for coated aggregate because of sticking and agglomerating characteristics		Materials that are poor bloaters		Materials that are too refractory (show no fusion or bloating when fired in stationary furnace at 2400 F for 5 minutes)		Materials that are too non-uniform in bloating qualitie	
Locality	Sample No.	Locality	Sample No.	Locality	Sample No.	Locality	Sample No.	Locality	Sampl No.
Ribstone Creek-shale	1,2	Edmonton-clay	6	Edson-bentonite	22,23	Stettler-shale	36	Edmonton-clay	3,4
Edmonton-clay	5	Stettler-shale	30	Stettler-clay	35	Gleichen-shale	46-48	Edmonton-shale	13,14
Edmonton-clay	7-12	Stettler-shale	31-34	Camrose-shale	37,39	Blairmore-shale	84,85	Edmonton- "	15,16
Edmonton-shale	17	Medicine Hat-clay	102-104	Gleichen-shale	49,51	Medicine Hat-shale	105	Edmonton- "	18
Edmonton-shale	21	Medicine Hat-shale	107	Brooks-shale	55			Edmonton-shale	19,20
Entwistle-shale	24-26			Drumheller-shale	62,63			Camrose-shale	40
Gwynne-shale	27,28			Coleman-shale	87			Sandstone-shale	41-43
Stettler-shale	29			Lethbridge-shale	96,97			Gleichen-shale	50
Camrose-shale	38							Brooks-shale	56
Turner Valley-clay	44							Brooks-shale	59,60
Turner Valley-shale	45							Drumheller-shale	64
Eyremore-shale	52,53							Drumheller- "	65
Brooks-shale	54							Drumheller-bentonite	66,67
Brooks-shale	57							Calgary-shale	69-73
Brooks-shale	58							Cochrane-shale	74
Brooks-clay	61							Jacob Creek- "	77,78
Drumheller-shale	68							Blairmore- "	79
Cochrane-shale	75							Blairmore- "	86
Ghost River-shale	76							Coleman- "	88
Blairmore-shale	80-83							Lethbridge- "	94
Bellevue-shale	89-92							Lethbridge- "	98
Lethbridge-shale	93							Lethbridge- "	99
Lethbridge-shale	95							Taber-shale	101
Lethbridge-shale	100							Medicine Hat-shale	106
								Medicine Hat-shale	108

Figure 4 - Summary of lightweight aggregate test results - Alberta

LOCATIONS, DESCRIPTIONS AND TEST RESULTS OF CLAYS AND SHALES IN ALBERTA

The shales and clays sampled in Alberta gave good results in the laboratory. Of the 108 samples tested, 40 taken from 24 occurrences showed good possibilities as raw materials for coated lightweight aggregate; 10 from five occurrences proved to be good natural bloaters but had narrow vitrification ranges; 13 from eight occurrences proved to be poor bloaters; seven from four occurrences were too refractory; and 38 samples from 25 occurrences proved to be too non-uniform. The results of the tests showed no correlation with the geological formation from which the samples were taken. It is apparent, however, that ample raw materials exist within an economic distance of the rapidly expanding Calgary and Edmonton markets. An abundance of low cost fuel adds further incentive to the establishment of lightweight aggregate industry in this province.

Descriptions of the occurrences sampled and the test results in the laboratory are given below.

RIBSTONE CREEK

Large amounts of shale are exposed in the Ribstone Creek valley. Samples believed to belong to the Ribstone Creek formation were secured in outcrops where Highway 14 crosses the valley. A geological section of the exposure was noted as follows:

Top soil	1 foot
Light brown sand	7 feet
Reworked shale	31.5 feet
Dark grey, iron-stained shale (Samples 1 and 2)	12 feet

Although the overburden where sampled is prohibitive, doubtless the same beds could be found under more favourable conditions. Sample 1 represented the upper five feet of the 12-foot exposure of shale, and Sample 2 the lower seven feet.

When fired in the stationary furnace both materials bloated well and had wide vitrification ranges. Sample 2 contained some sandy shale which showed no bloating under firing conditions that caused good expansion of the bulk of the material.

When fired in the rotary kiln, Sample 1 gave a good product weighing 42 lb./cu. ft. with a crushing strength, for one inch compaction, of 795 p.s.i. for the -3/8 inch + 8-mesh fraction. Overall volume expansion was 40 per cent and the maximum temperature permissible without agglomeration was 2035°F. The average kiln operating temperature for the run was 2025°F.

Sample 2 when fired in the rotary kiln gave a product weighing 66 lb./cu. ft. with a crushing strength of 1114 p.s.i. The overall volume expansion was 25 per cent, the maximum allowable temperature without agglomeration, 2050°F, and the average kiln operating temperature, 2030°. The bulk density of the product was high due largely to the presence of unbloated sandy shale particles. However, the main part of the sample bloated well.

These tests indicated that the shales in the Ribstone Creek area offer good possibilities as raw materials for coated aggregate. However, the obvious disadvantage of this area is its poor location with respect to the nearest building market at Edmonton.

EDMONTON

Clays

Two types of surface clay occur in the Edmonton area, namely, the flood plain clay underlying the flat terrace bordering the Saskatchewan River and the upper terrace lake clay on which the city is built. Both types are worked for the manufacture of brick, the former by Little and Sons Limited, and the latter by Acme Brick and Tile Company, Limited.

Samples of the flood plain clay were secured at the clay pit operated by Little and Sons Limited in the Riverdale district. A section of the deposit was noted as follows:

Top soil	1 foot
Silty clay (Samples 3 and 4)	10 feet
Sand	not measured

The silty clay represented by Samples 3 and 4 was not sufficiently uniform in bloating characteristics to warrant consideration as a raw material for coated aggregate. As tested in the stationary furnace most of the clay particles showed narrow vitrification ranges.

Samples of the upper terrace clay were obtained from Acme Brick Company's clay pit near Cannell. A section of the pit was measured as follows:

Top soil	2 feet
Well-bedded clay (Sample 5)	10 feet
Cross-bedded clay becoming more sandy with depth (Sample 6)	7 feet
Silt to floor of pit	5 feet

In the stationary furnace the upper clay (Sample 5) gave a well bloated product and showed a wide vitrification range. The underlying sandy clay (Sample 6) is slightly more refractory. It has a shorter vitrification range but bloats fairly well.

In the rotary kiln the upper clay (Sample 5) when pelletized to $-\frac{1}{2}" + \frac{1}{4}"$ size and dried gave a good product. Crushed to -3/8" + 8-mesh size it had a bulk density of 37 lb./cu. ft. and a crushing strength of 2045 p.s.i. for one inch compaction. The agglomerating temperature was about 2100°F and the average kiln temperature for the run was 2075°F. The approximate volume expansion was 15 per cent.

The sandy clay (Sample 6) did not give favourable results when tested in the rotary kiln. This material, because of its shorter vitrification range, did not show any volume expansion below 2150°F, at which temperature serious agglomeration began. The product was heavy and weak having a bulk density of 54 lb./cu. ft. and a crushing strength of 636 p.s.i.

Six samples of clay (Samples 7 to 12 inclusive) from sec. 16, tp. 52, r. 25, W. of 4 along the Saskatchewan River approximately five miles southwest of Edmonton, were submitted by the Research Council of Alberta for testing. These samples were from two seven-foot bore holes. One was drilled near the north bank of the river and the other 300 yards back from the river bank. This clay is believed to belong to the upper terrace clays such as are found at Acme Brick Company's pit described above.

Stationary furnace and rotary kiln tests made on these samples showed that the clay has good possibilities as a raw material for coated lightweight aggregate. The fine nature of the samples as received necessitated pelletizing before feeding to the rotary kiln. Each of the samples showed good bloating properties in the stationary furnace and each had a wide vitrification range. The rotary kiln products had bulk densities ranging from 33 to 47 lb./cu. ft. and crushing strengths from 796 to 1432 p.s.i. The volume expansions varied from 50 to 80 per cent. Average kiln temperatures were just below the agglomerating temperatures and varied from 2000°F to 2035°F.

In view of the nearness to the Edmonton market, the upper terrace clays such as tested at the above location and at the Acme Brick Company's pit north of Edmonton are considered to offer the best possibilities in the Edmonton area.

Shales

The district about Edmonton is underlain by the Edmonton formation which consists of bentonitic sandstone and shale, carbonaceous shale, and coal. A pronounced characteristic of the Edmonton formation is the variation in thickness and composition of the beds both laterally and vertically, which is unfavourable from the viewpoint of securing a uniform supply of raw material.

Shale is associated with the coal being mined in the various Edmonton district mines and from 15 to 30 tons of shale a day are hoisted and discarded at each mine. The waste piles that have accumulated over the years at the various mines are additional sources of shale, the volume of material varying at each mine from a few thousand to over 500,000 cubic yards. This waste material through spontaneous combustion has burned to a red or buff colour. Samples of the shale as mined and after burning on the waste dump were secured at four of the main mines in the Edmonton district.

At Beverly, on the eastern outskirts of Edmonton, a bentonitic shale (Sample 13) lies above and below the coal being mined at the Beverly coal mine. Sample 14 was a grab sample of the burned shale from the waste dump. When tested in the stationary furnace, both materials proved to be extremely non-uniform in bloating character. Approximately 50 per cent of each sample bloated well and showed a wide vitrification range while the remainder showed no bloating.

In the mine shale (Sample 13), the unbloated material was high in carbon while the bloated material appeared to be those particles that were highly bentonitic. In Sample 14, the shale from the dump, the unbloated material was composed of those particles high in sand content. Rotary kiln tests made on both materials confirmed the results of the stationary furnace work. The products obtained were unsatisfactory and extremely non-uniform.

Samples of the mine shale (Sample 15) and shale from the waste dump (Sample 16) were obtained from the Red Hot Coal Company, Limited, whose property is on the south side of the North Saskatchewan River on the eastern outskirts of Edmonton. When tested in the stationary furnace and rotary kiln, both of these materials proved to be extremely non-uniform in bloating character.

At the Black Diamond mine of the Great West Coal Company, Limited, on the N.W. $\frac{1}{4}$ sec. 7, tp. 53, r. 23, W. 4, about 30 tons of bentonitic shale (Sample 17) is mined from the roof of the coal seam daily. This sample when fired in the stationary furnace bloated exceptionally well and had a fairly wide vitrification range. The product, however, contained a few unbloated particles that were evidently too high in carbon.

When tested in the rotary kiln a fairly good product was obtained which, when crushed to -3/8" + 8-mesh, had a bulk density of 37 lb./cu. ft., and a crushing strength of 795 p.s.i. The approximate volume expansion measured 125 per cent. The agglomerating temperature was about 1980°F and the average temperature for the rotary kiln run was 1975°F.

This material had an exceptionally good volume expansion and good weight and strength properties. The main objection was that about 10 per cent of it was too high in carbon and did not show any bloating. It seems to offer good possibilities as a raw material for coated aggregate but material containing excess carbon should be avoided.

A grab sample (Sample 18) which was taken of the burned shale from the waste dump gave a non-uniform product in both the stationary furnace and rotary kiln. A satisfactory product could not be obtained in the rotary kiln, when fired below the temperature 2060°F at which serious agglomeration began.

At the Penn mine of Banner Coals Limited near Carbondale about 10 miles north of Edmonton, shale is mined from above and below the coal seam. Samples were secured of the mine shale (Sample 19) and the burned shale from the dump (Sample 20).

The mine shale particles proved to have varying fusion temperatures. In the rotary kiln test the maximum operating temperature was limited to that of the lowest fusing material at about 2025°F to avoid agglomeration. As a result a large part of the product was underbloated. The product had a bulk density of 47 lb./cu. ft., a crushing strength for one inch compaction of 636 p.s.i., and an overall volume expansion of 30 per cent. In view of its non-uniformity it is not considered to offer good possibilities as a raw material for coated aggregate.

The burned shale (Sample 20) from the waste dump proved to be extremely non-uniform in firing qualities when tested in both the stationary furnace and rotary kiln. The physical properties of the product were not determined.

Shale belonging to the Edmonton formation is exposed within the Edmonton city limits along the north side of the Saskatchewan River in the Highlands district. A seven-foot bed of concretionary, dark grey shale (Sample 21) was sampled at this location. Overburden, where sampled, amounts to about 10 feet of sloughed, glacial material but increases very rapidly to prohibitive amounts into the river bank.

This material showed good bloating properties in the stationary furnace. The rotary kiln product was quite good showing a bulk density of 52 lb./cu. ft., a crushing strength of 1830 p.s.i. and a volume expansion of 50 per cent. The average kiln temperature of the run was just below 1960°F at which temperature the charge started to agglomerate.

The comparatively high bulk density shown by the product could very probably be reduced by a longer kiln retention time. As to quality of product, this shale is considered to offer reasonably good possibilities as a coated aggregate raw material. Detailed prospecting in the area would be necessary to establish a uniform supply, and to obtain a better quarry site than that from which the sample was taken.

EDSON

A large deposit of non-swelling bentonite occurs near Bickerdike on the McLeod River on the N.E. $\frac{1}{4}$ sec. 6, and S.E. $\frac{1}{4}$ sec. 7, tp. 52, r. 18, W. of 5. A geological section of the deposit was noted as follows:

Top soil	3 feet
Massive sandstone	25 feet
Compact black shale	3 feet
Yellow bentonite (Sample 23)	0.7 feet
Bluish-grey bentonite (Sample 22)	4 feet
Concealed to river level	2 feet

The bentonite was observed outcropping beneath the water in the river so that it appears that the bed has a thickness of at least eight feet. The surrounding country contains areas where the massive sandstone overburden has been largely eroded.

The bentonite (Samples 22 and 23) when tested in the stationary furnace showed only slight bloating and had a narrow vitrification range. Rotary kiln tests were not considered warranted.

ENTWISTLE

Shale believed to belong to the upper part of the Edmonton formation is exposed on the south side of Highway 16 just west of Entwistle and about 70 miles by rail west of Edmonton. A geological section of the exposure was noted as follows:

Soft, bedded, grey sandstone	10 feet
Dark grey shale (Sample 26)	2 feet
Sandy brownish-grey shale (Sample 25)	1.5 feet
Dark grey compact shale (Sample 24)	6.5 feet
Lignite	not measured

The stationary furnace tests on the above samples showed that the dark grey shale (Sample 26) had good bloating properties, and a wide vitrification range. The sandy shale (Sample 25) was also an excellent bloater but did not have as wide a vitrification range as the upper shale. Sample 24 proved to be non-uniform. Most of it bloated well and had a wide vitrification range, the remainder being slightly more refractory and showing very little bloating or fusion under the same firing conditions.

When fired in the rotary kiln, the upper shale (Sample 26) gave a good product with a bulk density of 49 lb./cu. ft. and a crushing strength of 955 p.s.i. for one inch compaction. The volume expansion was approximately 40 per cent; the average kiln temperature was 1965°F, and the agglomerating temperature measured 1970°F.

The rotary kiln product from the sandy shale (Sample 25) was decidedly underbloated. Some bloating of this material took place before agglomeration but it was evident that a much greater retention time in the kiln would be necessary. The bulk density and crushing strength of the product measured 63 lb./cu. ft. and 1909 p.s.i. respectively, to give a high crushing strength-to-weight ratio. The volume expansion measured 20 per cent. The agglomerating temperature measured 1970°F while the average kiln temperature was 1960°F.

The lower, dark grey shale (Sample 24) gave a good product in the rotary kiln but showed the non-uniformity that was indicated in the stationary furnace tests. Approximately 10 per cent of the sample showed no bloating nor fusion under kiln conditions that produced good bloating for the remainder of the sample. The bulk density and crushing strength of the product were respectively 55 lb./cu. ft., and 1273 p.s.i. The overall volume expansion was low at 10 per cent. Agglomeration of the charge started at about 1970°F and the average kiln temperature was 1965°F.

Although the test results on the shales from Entwistle represented by Samples 24 to 26 were not particularly good with the exception of the upper two-foot width of shale (Sample 26), they were classed as having possibilities for coated lightweight aggregate manufacture.

GWYNNE

Shales belonging to the Edmonton formation outcrop on the south side of Highway 13, one mile west of the town of Gwynne, approximately eight miles west of Wetaskiwin, and 50 miles by rail south of Edmonton. Where sampled, the shale beds had a total width of 17 feet down to the road level. Overlying the shale was 10 to 15 feet of reworked shale and one to two feet of top soil. Sample 28 represented the top 14 feet of olive green, iron-stained shale while Sample 27 represented the lower three feet of the cut, and consisted of dark grey, iron-stained, carbonaceous shale.

Both materials were good bloaters when fired in the stationary furnace and both had wide vitrification ranges.

The olive green shale (Sample 28) gave a fairly good product in the rotary kiln but was obviously underbloated. A longer kiln retention time would probably have improved the bulk density which measured 65 lb./cu. ft. The crushing strength for one inch compaction was 1432 p.s.i.; the volume expansion, approximately 20 per cent; the agglomerating temperature, 2060°F; and the average kiln temperature, 2050°F.

The carbonaceous shale (Sample 27) gave a good product in the rotary kiln. The bulk density measured 47 lb./cu. ft. The crushing strength for one inch compaction was low at 478 p.s.i.; the volume expansion measured 40 per cent; the agglomerating temperature about 2080°F; and the average kiln temperature, 2040°F.

Both of these materials (Samples 27 and 28) have good bloating properties, possess a wide vitrification range and are considered to offer good possibilities as raw materials for coated lightweight aggregate.

STETTLER

Shale belonging to the Edmonton formation is stripped as overburden at the strip mine of the Stettler Coal Company, Limited, on l.s.d. 16, sec. 26, tp. 40, r. 16, W. of 4, approximately 30 miles northeast of Stettler. Sample 29 was representative of a seven-foot width of grey carbonaceous shale immediately overlying the eight-foot coal seam.

When tested in the stationary furnace most of this material bloated well, and had a wide vitrification range. However, the sample contained a small amount of sandy shale that showed no bloating. These results were confirmed in the rotary kiln test in which approximately 90 per cent of the sample was very well bloated with well-rounded particles. The remaining sandy material showed no bloating under these firing conditions. The overall volume expansion measured 50 per cent; the bulk density, 41 lb./cu. ft.; and the crushing strength, 636 p.s.i. The average kiln temperature was just below the agglomerating temperature of 2040°F. This material is considered to offer good possibilities as a coated lightweight aggregate material because of its wide vitrification range and good bloating properties. However, the objectionable sandy shale would have to be eliminated to give a uniform product.

Extensive amounts of burnt carbonaceous shale underlie only six inches to a foot of overburden in the vicinity of Paintearth Creek, approximately 25 miles northeast of Stettler. A four-foot thickness of this shale (Sample 30) was taken on the N.W. ¼ sec. 36, tp. 39, r. 16, W. of 4. When fired for short retention times in the stationary furnace, this material proved to be quite refractory showing no bloating nor fusion until a temperature of 2400°F had been reached. At this temperature the shale bloated well and uniformly but had a very narrow vitrification range. When fired in the rotary kiln there was no evidence of bloating below the temperature at which serious agglomeration started. The physical properties of the product were not determined.

Clay and shale is abundantly exposed between Alix and Nevis on the Lacombe branch of the Canadian Pacific Railway, approximately 20 miles west of Stettler. The most noticeable feature of the exposures is a pronounced bed of white clay. A geological section measured on a butte on the N.W. ¼ sec. 15, tp. 39, r. 22, W. 4, was noted as follows:

Top soil	6 inches
Reworked shale and sandstone	8 feet
Black carbonaceous shale (Sample 36)	1.5 feet
White clay (Sample 35)	4 feet
Greenish-grey, iron-stained shale (Sample 34)	2 feet
Black, highly carbonaceous shale (Sample 33)	1 foot
Chocolate brown shale (Sample 32)	1.5 feet
Greenish-grey, iron-stained shale (Sample 31)	3 feet

When tested in the stationary furnace Samples 36, 35, 34, 33 and 32 all proved to be quite refractory. The black carbonaceous shale (Sample 36) showed no bloating nor fusion when fired at 2400°F for five minutes. The white clay (Sample 35) showed only very slight bloating and fusion at the same temperature and heating time. The greenish-grey shale (Sample 34), the black shale (Sample 33), and the brown shale (Sample 32) all bloated well at 2400°F but had narrow vitrification ranges. The lower greenish-grey shale (Sample 31) proved to be too non-uniform. Approximately half of the sample bloated well and had a wide vitrification range but the remainder showed no bloating. None of these materials, i.e. Samples 31 to 36 inclusive were considered good enough to warrant rotary kiln tests.

CAMROSE

A large tonnage of shale is being stripped as overburden at the strip mine of Camrose Collieries Limited, on the S.W. ¼ sec. 29, tp. 46, r. 19, W. of 4., a few miles southeast of Camrose. A geological section measured from the surface to the coal seam was noted as follows:

Top soil	1 foot
Glacial clay	10 - 12 feet
Variegated shale (Sample 40)	7 feet
Chocolate brown, highly carbonaceous shale (Sample 39)	2 feet
Greenish-grey shale, parts sandy (Sample 38)	5 feet
Black carbonaceous shale (Sample 37)	7 feet

The variegated shale (Sample 40) when tested in the stationary furnace proved to be non-uniform. Some parts were well bloated with a wide vitrification range while others were excessively high in carbon or sand content and showed no bloating. When tested in the rotary kiln the same non-uniformity was indicated. The part of the sample that was well bloated gave the product an overall volume expansion of 35 per cent. The bulk density was 52 lb./cu. ft.; the crushing strength, 1432 p.s.i.; the average kiln temperature, 2005°F; and the agglomerating temperature, 2025°F. Due to the non-uniformity of this material it was not considered to possess good possibilities as a raw material for coated lightweight aggregate.

The brown shale (Sample 39) and the black shale (Sample 37) both showed too high a content of carbon when tested in the stationary furnace. The particles of each sample showed slight surface bloating but contained an unbloated, black, carbon core.

Rotary kiln tests on these two materials gave poor products. The interiors of the particles in each case consisted of an unbloated black carbon core. Sample 39 gave no volume expansion while Sample 37 had a volume expansion of 15 per cent. Preheating at a temperature high enough to remove the excess carbon would undoubtedly improve the bloating qualities of these materials but in view of their high carbon content and consequent poor bloating properties they are not considered to offer good possibilities as raw materials for coated lightweight aggregate.

The greenish-grey shale (Sample 38) lying between the above two materials showed good bloating properties and a wide vitrification range in the stationary furnace. The rotary kiln product was also good. A small amount of unbloated sandy shale was present but otherwise the product was uniform, and the particles light, strong and well-rounded. The volume expansion measured 60 per cent; the bulk density 47 lb./cu. ft.; and the crushing strength 1034 p.s.i. The average kiln temperature was 1995°F, and the agglomerating temperature, 2010°F.

The tests on the shales from the strip mine of Camrose Collieries Limited indicated that only the greenish-grey shale (Sample 38) has good possibilities as a raw material for coated lightweight aggregate. It has a width of only five feet and is overlain by 20 feet of overburden which, of course, would have to be removed anyway in the mining of the coal. However, it is doubtful if the tonnage available in the normal stripping operations would warrant its consideration as a coated lightweight aggregate raw material.

SANDSTONE

Paskapoo shales are well exposed in the old quarry of the Canada Cement Company Limited near Sandstone station on the Calgary-McLeod branch of the Canadian Pacific Railway. A geological section was noted as follows:

Glacial overburden		10 feet
Interbedded sandstone and shale		±50 feet
Massive sandstone		4 feet
Blue-grey shale	(Sample 43)	7 feet
Black carboniferous shale	(Sample 43)	1 foot
Grey weathering sandy shale (Samples 41 and 42)		10 feet
Concealed to floor of pit		30 feet

When tested in the stationary furnace Sample 43 showed non-uniformity. Part of the blue-grey shale was well bloated with a wide vitrification range whereas part showed no expansion under the same conditions of time and temperature. The black shale included in the sample showed no bloating at time-temperature conditions that produced bloating in part of the blue-grey shale. These results were confirmed in the rotary kiln, the product being extremely non-uniform. Approximately 50 per cent of the sample was well bloated, the remainder showing little or no bloating. The volume expansion measured 50 per cent; the bulk density 57 lb./cu. ft.; and the crushing strength 1591 p.s.i. The average kiln temperature was just under the agglomerating temperature of 2025°F.

The grey weathering shale represented by Samples 41 and 42 also proved to be non-uniform. Each sample bloated well but contained materials with different vitrification ranges varying from wide to very narrow. Because of the non-uniformity in vitrification ranges these samples were not tested in the rotary kiln.

TURNER VALLEY

A fine-grained, colloidal, recent clay is exposed in the channel cut by the north branch of the Sheep River. It is reported that this material, because of its high colloidal qualities, has found usage in the past as a drilling mud material in the Turner Valley oil field. A sample of the clay was obtained from a river cut in the S.W. $\frac{1}{4}$ sec. 12, tp. 21, r. 3, W. 5.

The following section was measured:

Boulder clay overburden	10 to 12 feet
Plastic dark brown clay containing a few scattered pebbles down to water level (Sample 44)	15 feet

Stationary furnace tests on this clay (Sample 44) showed it to be an excellent bloating material possessing good uniformity. The rotary kiln test also gave a good product but it was evident that fairly close temperature control would be necessary to prevent agglomeration which took place rapidly after the critical temperature of about 1950°F was reached. The bulk density of the product measured 43 lb./cu. ft.; the crushing strength, 795 p.s.i.; and the overall volume expansion, 30 per cent. The temperature of the run ranged from 1940°F to 1980°F.

As to quality, this material is considered to have good possibilities as a coated lightweight aggregate raw material. However, the extra cost of a truck haul to rail of about 20 miles would very likely be prohibitive.

At the town of Turner Valley, approximately six miles south of the previous location, hard, black, steep-dipping shale belonging to the Alberta formation is exposed in abundance on the banks of the south branch of Sheep River. In most places the overburden is very thin. A five-foot section of the shale (Sample 45) was taken on l.s.d. 1, sec. 1, tp. 20, r. 3, W. 5. In the stationary furnace this material showed fairly good bloating properties. In the rotary kiln a fair product was obtained weighing 55 lb./cu. ft. with a crushing strength of 875 p.s.i. The volume expansion measured 50 per cent while the average kiln temperature was 2170°F and the maximum temperature to avoid agglomeration, 2190°F. The product was not very uniformly bloated and there was no rounding of the particles during the firing process.

The material possesses a fairly wide vitrification range and fair bloating properties so, for these reasons, must be considered as having possibilities as lightweight aggregate material from the point of view of quality of product. However, with the previous material, a truck haul of about 13 miles to rail would very probably prohibit the economic use of this shale as a lightweight aggregate raw material.

GLEICHEN

Shale belonging to the Edmonton formation outcrops near Gleichen close to the main line of the Canadian Pacific Railway east of Calgary on the S.W. $\frac{1}{4}$ sec. 24, tp. 22, r. 23, W 4. A geological section was noted as follows:

Top soil and reworked shale	5 feet
Grey bentonitic shale (Sample 51)	10 feet
Dark carbonaceous shale (Sample 50)	9 feet
Grey shale (Sample 49)	6 feet
Highly carbonaceous shale (Samples 47 and 48)	12 feet
Light grey shale (Sample 46)	7 feet
Sandstone	4 feet

The light grey shale (Sample 46) proved to be too refractory when tested in the stationary furnace. The shale showed no bloating nor fusion when fired at 2400°F for five minutes.

The carbonaceous shale (Samples 47 and 48) was also quite refractory and showed only very slight bloating properties when fired at 2400°F.

The grey shale (Sample 49) when fired in the stationary furnace showed a slight amount of bloating and was not quite so **refractory** as the previous materials. However, when fired in the rotary kiln at just under the agglomerating temperature of 2180°F, a poor product, showing no volume expansion, was obtained.

The carbonaceous shale (Sample 50) overlying the grey shale proved to be non-uniform and to have poor bloating qualities in the stationary furnace.

The uppermost bentonitic shale (Sample 51) proved to have only fair bloating qualities in the stationary furnace. The rotary kiln test made at just under the agglomerating temperature of 2200°F gave a poor product showing no volume expansion.

In view of the poor results obtained on each of the materials from the exposure samples at Gleichen, these shales are not recommended for the production of coated lightweight aggregate.

EYREMORE

Large quantities of shale are being stripped as overburden at the Eyremore strip mine located in l.s.d. 1, sec. 23, tp. 17, r. 17, W. 4. A geological section was measured as follows:

Boulder clay	3 feet
Dark grey, thin-bedded, iron-stained shale (Sample 53)	3.5 feet
Dark compact grey shale (Sample 52)	8 feet
Light grey, thin-bedded, bentonitic sandstone	± 15 feet
Coal	9 feet

It is believed that the upper part of the section to the top of the bentonitic sandstone belongs to the Bearpaw formation and the lower, to the Oldman formation.

The lower eight feet of dark grey shale bloated very well in the stationary furnace and had a wide vitrification range. This material was evidently somewhat high in carbon content as evidenced by the dark-coloured interior of the particles. The rotary kiln product also showed a high content of carbon but had very good physical properties. The volume expansion measured 80 per cent while the bulk density and crushing strength were respectively 44 lb./cu. ft. and 1273 p.s.i. The average kiln temperature for the run was 2035°F while the agglomerating temperature was 2050°F.

The overlying 3.5 feet of thin-bedded grey shale bloated well in the stationary furnace and had a wide vitrification range. In the rotary kiln a fairly good product was obtained weighing 40 lb./cu. ft. with a crushing strength of 955 p.s.i. for one inch compaction. The degree of volume expansion was high at 75 per cent. The average kiln temperature was 1995°F and the agglomerating temperature, 2000°F.

The only objection to this material was that the product contained a considerable amount of thin, weak, platy material that was not well bloated. This could be expected from the thin-bedded nature of the raw material.

As a result of these tests both materials represented by Samples 52 and 53 are considered as suitable raw materials for a coated lightweight aggregate. However, both materials are decidely different in bloating properties and would probably have to be fired separately to give a uniform product.

BROOKS

Eight samples of shale were submitted by the Industrial Development Department, Canadian Pacific Railway Company, from the Brooks area on the railway line between Medicine Hat and Calgary, approximately 110 miles southeast of Calgary. The following descriptions of the various deposits are taken from company field reports.

Shale belonging to the Oldman formation is exposed on l.s.d. 13, sec. 16, tp. 18, r. 14, W. 4, two miles south of Brooks. Overburden is extremely light over a large area. A geological section of the exposure is as follows:

Top soil	1 foot
Light brown, iron rich, fissile shale with some tiny coal seams (Sample 55)	2.5 feet
Black bituminous shale with a little coal	0.5 feet
Dark grey weathering shale (Sample 54)	3.0 feet

Underlying the dark grey shale (Sample 54) to the bottom of the exposure is eight inches of very fissile dark grey shale with ironstone concretions.

The lower dark grey weathering shale (Sample 54) bloated well in the stationary furnace and had a wide vitrification range. A very good product was obtained in the rotary kiln. The bulk density was exceptionally low at 24 lb./cu. ft. As would be expected, the crushing strength was also very low and could not be measured with the equipment on hand. The volume expansion was very high at 100 per cent. The average kiln temperature for the run was just under 2000°F at which temperature agglomeration started. The low strength of this aggregate was due largely to its being over-bloated, which could be improved by shortening the kiln retention time at the expense of an increase in weight.

The upper 2.5 feet of fissile shale (Sample 55) showed poor bloating characteristics in the stationary furnace due largely to the excessive content of carbonaceous matter. Rotary kiln tests were not made.

Shale (Sample 56) from the Oldman formation was sampled on l.s.d. 12, sec. 28, tp. 18, r. 14, W. 4, one-half mile south of Brooks. The lower four feet of the exposure, which totalled six feet, was sampled. This material bloated well in the stationary furnace and had a wide vitrification range. The shale was apparently high in carbon as evidenced by the black colour of the interiors of the expanded particles. The rotary kiln product showed a volume expansion of 40 per cent, most of which was shown by the portion of the material with a low carbon content. The high carbon portion of the sample showed little, if any, expansion. For these reasons this material was classed as being too non-uniform for coated aggregate manufacture.

Shale belonging to the Bearpaw formation is exposed for a length of about 300 feet on the south side of the irrigation canal, 200 feet south of the railway at a point four miles west of Brooks. A geological section of the exposure is as follows:

Boulder clay	7 to 8 feet
Dark grey shale to water level of canal (Sample 57)	11 feet

Extensive areas of this shale south of the canal could be readily stripped.

In the stationary furnace this shale (Sample 57) proved to be an excellent bloater with a wide vitrification range. In the rotary kiln a well-rounded, light, and strong product was formed having a bulk density of 40 lb./cu. ft., and a crushing strength of 1193 p.s.i. The volume expansion measured 40 per cent. The average temperature of the kiln was 1985°F while agglomeration of the charge started at about 2010°F. The material is thought to have good possibilities for the manufacture of a good quality product.

Samples of shale were submitted from an exposure of the Bearpaw formation on the north flank of Spring Hill, one mile southwest of Countess. The hill is underlain by a large reserve of shale and overburden might not be as deep as indicated in the geological section which was measured at the brow of the hill. This section is as follows:

Overburden	15 feet
Impure bentonite (Sample 60)	7 feet
Light grey to nearly black fissile shale (Sample 59)	10 feet
Black to greenish-grey shale (Sample 58)	10 feet
Dark grey shale	5 feet

These shales are thin-bedded and mostly very fissile, and quite variable in character.

The lower black to greenish-grey shale (Sample 58) bloated well in the stationary furnace and had a fairly wide vitrification range. A good product weighing 30 lb./cu. ft. was obtained in the rotary kiln. The crushing strength was too low, however, for measurement with the equipment on hand. The volume expansion measured 40 per cent. The average kiln temperature for the run was 1985°F while agglomeration of the charge started at about 2000°F.

The overlying light grey to nearly black fissile shale (Sample 59) gave a well-bloated product in the stationary furnace and had a wide vitrification range. The rotary kiln product was rather poor,showing an abundance of thin, unexpanded, weak, platy material. For this reason it was classed as being too non-uniform for consideration as a possible raw material.

The upper seven feet of impure bentonite (Sample 60) gave an extremely non-uniform product in both the stationary furnace and rotary kiln. Approximately 50 per cent of the sample showed good bloating characteristics while the remainder showed none under the same firing conditions.

Of the three materials sampled (Samples 58 to 60) at this location only the bottom 10 feet of shale (Sample 58) is considered to offer good possibilities as a raw material for coated aggregate. The type of product produced from this shale would be one of low weight and low strength and hence would find application only where these properties were desired.

On sec. 31, tp. 16, r. 10, W. 4, north of Alderson,recent clay is exposed in the bottom of a dry lake bed. The northeast end of the dry lake bed is seven and one-half miles north of Alderson and the southwest end is four and one-half miles east of Kininvie on the Medicine Hat-Calgary line of the Canadian Pacific Railway. The dry lake bed which has an area of roughly 480 acres is composed of light grey, plastic, non-calcareous clay (Sample 61). Its bottom was not found in a three-foot auger hole.

This clay (Sample 61) proved to be an excellent bloater with a wide vitrification range. When fired in the rotary kiln at an average temperature of 1965°F the material showed a volume expansion of 75 per cent giving a product weighing 29 lb./cu. ft. The wide vitrification range enabled easy kiln control and good expansion below 1980°F at which temperature agglomeration tended to start. The crushing strength measured 477 p.s.i. for one inch compaction. This material is considered to offer good possibilities as a coated aggregate raw material because of its wide vitrification range and good bloating properties.

DRUMHELLER

Shale belonging to the Edmonton formation is associated with the coal being mined at the various mines in the Drumheller area. Most of the mines also have a large waste pile of shale but these are usually very impure, containing coal, sandstone, and, in some cases, silicified wood so that they would be of little importance to the lightweight aggregate manufacturer.

At Rosedale Collieries Limited, Rosedale, a sample (62) was taken of the burnt shale on the waste dump and another (63) was taken underground representing a three-foot width of carbonaceous shale that was being mined with the No. 1 coal seam.

Neither of these materials proved to be of much value. The dump material (Sample 62) had a narrow vitrification range and showed only slight bloating qualities at temperatures approaching what is considered the commercial limit. The mine shale (Sample 63) was a very poor bloater showing only surface bloating due to the high carbon content.

A sample of shale (64) was secured from the waste dump at Western Gem and Jewel Collieries, Limited, Cambria. This material gave poor results due to its non-uniformity. Among the impurities were coal, bentonite, and silicified wood.

Several million cubic yards of burnt shale with little to no overburden are easily available at Wayne. Sample 65 was taken of this material from an exposure in one of the many pronounced buttes approximately one-half mile west of the mine of Aetna Coals Limited. This shale also proved to be too non-uniform for consideration as a coated lightweight aggregate raw material.

On sec. 14, tp. 29, r. 20, W. of 4, just north of Drumheller shale is stripped as overburden in the mining of a three and one-half to four-foot bed of bentonite. The bentonite and overlying bentonitic shale were sampled primarily for drilling fluid tests but were also tested as possible materials for lightweight aggregate. A geological section measured at the strip mine from the surface to the floor of the pit is as follows:

Massive brown weathering sandstone	6 feet
Shale	7.5 feet
Shale and sandstone	7 feet
Coal	5.5 feet
Carbonaceous shale	7 feet
Bentonitic clay	1 foot
Dark grey, hard, bentonitic shale (Sample 68)	9 feet
Bentonitic shale grading downward to massive green bentonite (Sample 67)	6" to 4 feet
Olive green, thin-bedded, bentonite (Sample 66)	7" to 1 foot
Grey bentonitic sandstone	3 feet

The bentonite represented by Samples 66 and 67 did not offer much promise as raw materials for lightweight aggregate. Both samples were non-uniform, showed only a medium degree of bloating and had narrow vitrification ranges. The overlying bentonitic shale (Sample 68) gave very good results in both the stationary furnace and rotary kiln. This material bloated well and had a wide vitrification range enabling easy treatment in the rotary kiln. The rotary kiln product showed a volume expansion of 40 per cent, a bulk density of 52 lb./cu. ft. and a crushing strength for one inch compaction of 1511 p.s.i. The average kiln temperature was 1995°F and the agglomerating temperature about 2030°F. This shale, therefore, offers good possibilities as a raw material for coated lightweight aggregate. However, the amount of overburden would be prohibitive and, the amount stripped in the normal mining of the bentonite, would provide only a small part of the tonnage required. In addition, variations in thickness and in composition both laterally and vertically which are characteristic of the Edmonton formation would have to be contended with.

A large deposit of bentonite was located and sampled by A.S. Dawson, Geologist, Industrial Development Department of the Canadian Pacific Railway at Dorothy, approximately 22 miles southwest of Drumheller. The deposit is on l.s.d. 10, sec. 9, tp. 27, r. 17, W. 4 adjacent to the railway at Dorothy. As a large tonnage was readily available with little to no overburden, it was hoped that it would prove of value as a lightweight aggregate raw material. However, tests made in both the stationary furnace and rotary kiln on several samples from the deposit indicated that the material was a poor bloater with a narrow vitrification range.

CALGARY

The region around Calgary is underlain by Tertiary shales and sandstone but exposures are rare owing to the heavy mantle of glacial drift. At Brickburn, just west of Calgary on the main line of the Canadian Pacific Railway, shale and sandstone belonging to the Paskapoo formation is well exposed in a pit formerly operated for the production of brick. A geological section measured in the pit was as follows:

Glacial till and reworked shale		3 feet
Massive light brown sandstone		5 feet
Interbedded sandstone and shale		1 foot
Dark grey, slightly iron-stained shale (Sample 73)		3.5 feet
Massive light brown sandstone		3 feet
Variegated shale (Sample 72)		3 feet
Massive light brown sandstone containing three shale lenses varying in thickness from 6 inches to 2 feet		5 to 7 feet
Dark grey (almost black) shale	(	2 feet
Greenish-grey, iron-stained shale	(	2 feet
Sandy shale grading from light brown colour to olive green and containing some shaley sandstone	(Sample 71)	4 feet
Light blue shale	(	1 foot
Light brown, sandy, iron-stained shale	(Sample	4 feet
Olive green, iron-stained shale	70)	3 feet
Massive light brown sandstone		3 feet

Light brown, iron-stained shale (pts. sandy) (Sample 69)	4 feet
Concealed to floor of pit	25 feet

All the shales sampled at this location proved to be non-uniform when tested in the stationary furnace. Portions of the material represented by Samples 69 and 70 showed poor bloating with narrow vitrification ranges while the sandy phases showed no bloating under the same conditions. Sample 71 composed of material from four individual shale beds showed different bloating properties and various vitrification ranges. The variegated shale represented by Sample 72 bloated well but part of the sample had a narrow vitrification range. The upper grey, iron-stained shale (Sample 73) also contained some material with a narrow vitrification range and some that did not bloat at conditions that caused good bloating of part of the sample.

Rotary kiln tests were made on Sample 71 representing nine feet of shale and Sample 72 representing three feet of shale overlying the former (Sample 71) but separated from it by from five to seven feet of sandstone. Serious agglomeration of portions of each material started at about 2070°F. Below this temperature the bulk of each material showed very little, if any, bloating. Small portions, however, were well expanded. No physical properties were determined.

In view of the non-uniformity of the materials tested, the Paskapoo shales at this location are not recommended as raw materials for coated lightweight aggregate manufacture. However, the location with respect to the Calgary market and a supply of natural gas fuel is such as to warrant careful prospecting in the immediate vicinity in the hope of finding a sufficient thickness of uniform material where the interbedded sandstone is at a minimum.

COCHRANE

The area about the town of Cochrane on the main line of the Canadian Pacific Railway approximately 25 miles northwest of Calgary, is underlain by Paskapoo shales and sandstone. A nine-foot width of shale (Sample 74) was sampled in a highway cut approximately one and one-half miles east of Cochrane in the N.E. ¼ sec. 1, tp. 26, r. 4, W. 5. The shale varied in colour from dark grey (almost black) to light brown and was overlain by from 20 to 35 feet of massive, light brown, sandstone. The cost of removing the sandstone overburden would be prohibitive but it was felt that the sample would give some idea as to the character of the shale for the locality. Lower down in the valley this capping of sandstone has been eroded.

When tested in the stationary furnace this shale proved to be non-uniform in bloating qualities. Approximately 60 per cent of the sample bloated well but had a narrow vitrification range and the remainder showed no bloating under the same conditions of firing. The material was, therefore, not considered worthy of rotary kiln tests.

At Grand Valley Creek, six miles by highway west of Cochrane, shale believed to belong to the Edmonton formation is well exposed in the creek banks. A 10-foot width of highly contorted greenish-grey shale (Sample 75) was sampled on the south bank of the creek on the east side of the highway bridge. The legal location is the S.W. ¼ sec. 24, tp. 26, r. 5, W. 5. Where sampled, the overburden consisted of from 0 to 15 feet of inter-bedded sandstone and shale, and two feet of stream gravel.

This material showed good bloating properties and had a wide vitrification range in the stationary furnace. In the rotary kiln, a good product was obtained showing a volume expansion of 75 per cent, a bulk density of 49 lb./cu. ft. and a crushing strength for one inch compaction of 636 p.s.i. for the -3/8" + 8-mesh fraction. The average kiln temperature for the run was 2035°F while slight clustering of the charge started at about 2040°F.

As to quality of product, this shale has good possibilities as a raw material because it gives a uniform, well-bloated product below the temperature at which agglomeration begins which enables easy kiln control. The location of the deposit is also good except that it is on the opposite side of the Bow River to the railroad. This would mean a truck haul of about six miles to the rail at Cochrane. As the material tested came from a disturbed or faulted zone, the extent and condition of this shale would have to be determined. Careful prospecting on the other side of the river might reveal a suitable deposit of the shale near the railway.

GHOST RIVER

A sample of compact, black shale (Sample 76) believed to belong to the upper Alberta formation was taken on the west bank of the Ghost River approximately one-half mile upstream from the highway bridge. The shale beds at this point dip at a high angle (almost vertical), and are overlain by about 10 feet of gravel.

In the stationary furnace this material proved to have good bloating qualities with a fairly wide vitrification range. It also proved slightly more refractory than most clays and shales necessitating a higher than average firing temperature.

In the rotary kiln a fair product was obtained weighing 54 lb./cu. ft., and with a crushing strength for one inch compaction of 1034 p.s.i. The volume expansion measured 70 per cent; the average kiln temperature, 2080°F; and the temperature at which troublesome agglomeration began was about 2100°F. In view of the degree of expansion shown by this shale at a temperature below the agglomerating temperature it is considered to offer possibilities as a raw material for lightweight aggregate. However, the product obtained in this test was somewhat heavy and did not show any rounding of the individual particles as is evident in most other good materials.

The distance by road to the railway at Cochrane, approximately 12 miles, and the steep dipping character of the beds of the Alberta formation are unfavourable to the economic development of the deposit.

JACOB CREEK

Two samples of shale were taken where Jacob Creek enters the Bow River about mid-way between Cochrane and Kananaskis and approximately six miles southwest of the mouth of the Ghost River, to get information on the firing qualities of the lower Alberta formation.

Sample 77 of steep dipping, compact, black shale was taken from a point 50 feet upstream from Highway 2 on the east side of the creek. It was taken over a width of five feet which was all that was exposed. The shale is overlain by ±5 feet of overburden. Sample 78 was taken on the west side of the creek and represented a 10-foot width of light grey weathering, fissile shale. Overburden of glacial material at this point is ±5 feet increasing rapidly back into the hill.

Both materials proved to be non-uniform in the stationary furnace, showed slight bloating, and had narrow vitrification ranges. For these reasons rotary kiln tests were not made.

BLAIRMORE

Numerous exposures of shale occur on York Creek just west of the town of Blairmore and a large amount of black shale believed to belong to the Alberta formation is exposed on the east fork of York Creek about one-half mile upstream from the forks or approximately two miles southwest of Blairmore. The shale dips about 60° to the West and has a strike of N.W.-S.E. The stream closely parallels the strike of the beds for a distance of about 1500 feet where shale is exposed in both creek banks for a stratigraphic width of at least 100 feet and a length of 1500 feet. Sample 79, representing a width of 10 feet, was taken on the west bank of the creek.

In the stationary furnace the shale represented by Sample 79 proved to be non-uniform, high in carbon with poor bloating qualities, and possessed a narrow vitrification range. Because of these poor qualities rotary kiln tests were not made.

Greenish-coloured shales, believed to belong to the Blairmore formation, are well exposed near the mouth of York Creek which crosses the beds at right angles to the strike which is approximately N.-S. The beds dip to the west at an angle of about 60°.

A geological section of the exposure was noted as follows:

Impure dark grey quartzite	not measured
Greenish-grey shale (Sample 83)	11 feet
Impure grey sandstone	17 feet
Greenish-grey shale (Sample 82)	11 feet
Impure grey sandstone	5 feet
Black shale with some sandy phases (Sample 81)	7 feet
Concealed	30 feet
Black shale	3 feet
Impure grey sandstone and sandy shale	7 feet
Concealed	30 feet
Dark greenish-grey shale	3 feet
Impure grey sandstone	11 feet
Greenish-grey shale with some narrow sandy lenses (Sample 80)	9 feet
Impure greyish-green sandstone	10 feet
Concealed	30 feet
Impure grey sandstone and shaley sandstone	± 15 feet

The above beds are overlain by approximately two feet of top soil overburden.

The greenish-grey shale (Sample 83) proved to be a good bloater with a wide vitrification range when tested in the stationary furnace. In the rotary kiln a somewhat heavy product was made with a weight of 58 lb./cu. ft. which may have been due to too short a kiln retention time. The crushing strength for one inch compaction measured 1750 p.s.i.; the volume expansion, 50 per cent; the average kiln temperature, 2025°; and the temperature at which agglomeration began, 2030°F. Although the product formed in the one rotary kiln test was too heavy, this shale has good possibilities as a raw material for lightweight aggregate.

Material from the other three shale beds sampled from this outcrop showed similar firing properties. Each was a good bloater with a wide vitrification range, and each has excellent possibilities as a raw material. The operating temperatures for the three rotary kiln runs were just below the agglomerating temperature of 2030°F; volume expansions ranged from 80 to 110 per cent; and bulk densities, from 43 to 50.

However, the unfavourable mining conditions created by the steep dipping character of the formation and the presence of the sandstone beds which would have to be removed would prove detrimental to the economic utilization of the shales from this exposure. The Blairmore shales at this location at least appear to be uniform in their firing qualities over a considerable width. Careful prospecting in the area might possibly reveal suitable material occurring under more favourable mining conditions. As to location the deposit is within half a mile of the railway but considerably farther from Alberta markets than many other materials tested.

Samples were secured of the shale believed to belong to the Kootenay formation which is being stripped as overburden at the No. 3 Strip mine of West Canadian Collieries, Limited, north of Blairmore.

A geological section from the surface to the No. 1 coal seam was noted as follows:

Conglomerate	variable
Iron-stained shale (Sample 86)	5 feet
Interbedded coal and shale	3 feet
Iron-stained, black carbonaceous shale (Sample 85)	8 feet
Light brown sandstone	4 feet
Iron-stained, black carbonaceous shale (Sample 84)	11 feet
Coal	1 foot
Iron-stained, black carbonaceous shale	3 feet
Coal (No. 1 Seam)	not measured

The upper shale (Sample 86) proved to be a very non-uniform when tested in the stationary furnace. Part bloated well with a fairly wide vitrification range while the remainder showed no bloating. The shales represented by Samples 84 and 85 were too refractory showing no evidence of bloating and only slight fusion when fired at 2400°F for five minutes. Both products contained a few pellets of metallic iron.

COLEMAN

Shale exposures are numerous in the Coleman area. A sample of black, soft, carbonaceous shale (Sample 87) was taken from a road cut on the Crowsnest-Coleman road approximately one mile east of Crowsnest Lake. The sample represented a 10-foot stratigraphic width. Overburden consisted of about one foot of top soil.

In the stationary furnace this material proved to be only a fair bloater with a medium to short vitrification range. The rotary kiln test also revealed a poor product.

Black, gypsiferous shales, overlain by five feet of reworked shale and boulder clay, are exposed in a cut on the north side of the Crowsnest-Coleman road at a point two miles west of the Coleman railway station. Sample 88 taken from a 20-foot width of shale at this location proved to be non-uniform in bloating qualities. Part of the material bloated well while part showed no bloating, so rotary kiln tests were not considered warranted.

A large tonnage of dark grey shale believed to belong to the Alberta formation is readily available on the eastern outskirts of Coleman where there are only a few inches of overburden. The shale appears to be uniform but the sample taken from this occurrence was lost in transit so that no information is available on its burning qualities.

BELLEVUE

An extensive tonnage of uniform, thin-bedded, grey shale belonging to the Fernie formation is exposed on Webb Creek Summit, approximately seven miles south of Bellevue, on the road to the Adanac strip mine. The beds dip at an angle of about 45°. Overburden over a large area is not more than two feet. Four samples (89 to 92), each representing a width of five feet were taken across a 20-foot width of the shale. This shale when ground to -200-mesh has been used by West Canadian Collieries, Limited in the heavy media separation of coal.

Each of the samples taken from this occurrence behaved alike in firing properties. Each had good bloating properties with a wide vitrification range. The rotary kiln products ranged in bulk density from 27 to 37 lb./cu. ft. and volume expansions, from 60 to 80 per cent. The crushing strengths were low varying from 159 to 477 p.s.i. for one inch compaction. The rather weak character of the product could be attributed to the thin-bedded character of the shale, and its resulting tendency to break into weak, thin, platy particles. The kiln temperature for the rotary kiln runs was kept at just under the agglomerating temperature of 1975°F.

This shale has good possibilities as a raw material for coated lightweight aggregate. The product obtained could be expected to have a low strength and a very light weight and could conceivably find use where high strength was not desired. If a good width of formation proved uniform, as it appears to be, mining could easily be accomplished. The deposit is approximately seven miles from the railway, and about 165 miles by rail from the nearest large market at Calgary.

LETHBRIDGE

Samples of waste mine shale (Sample 93) of the Bearpaw formation from the Galt mine of Lethbridge Collieries Limited were submitted for lightweight aggregate tests by the Industrial Development Department of the Canadian Pacific Railway Company. A sample of the burned red shale (Sample 94) from the mine dump was also submitted.

The mine shale (Sample 93)gave good results in both the stationary furnace and rotary kiln. Strong and fairly uniformly-bloated products weighing from 39 to 46 lb./cu. ft. were produced, the average volume expansion being 70 per cent. The best product made in this series of runs had a volume expansion of 75 per cent, a bulk density of 42 lb./cu. ft. and a crushing strength of 1350 p.s.i. The kiln operating temperature was just below the agglomerating temperature of 2160°F. As may be seen from the above the crushing strength to weight ratio was very high.

The burned shale from the mine waste dump (Sample 94) bloated fairly well in the stationary furnace but its vitrification range was too short to allow satisfactory bloating in the rotary kiln below the temperature at which agglomeration took place. Moreover, it was not uniform in bloating properties, a considerable amount of the material showing no bloating.

Bearpaw shale is exposed on Little Bow River in the N.W. ¼ sec. 14, tp. 12, r. 20, W. 4. about five miles from the Lethbridge-Turin branch of the Canadian Pacific Railway and about 25 miles by rail north of Lethbridge. A geological section was noted as follows:

Boulder clay		10 feet
Sandy, light brown, shale		1 foot
Light grey shale	(	1 foot
Black carbonaceous shale	((Sample 97)	2.5 feet
Light grey sandy shale	(	1 foot
Yellow bentonitic, iron-stained shale		1 foot
Greenish-grey, iron-stained, shaley sandstone		1 foot
Light grey, iron-stained shale (Sample 95)		5 feet
Concealed to river level		7 feet

The lower, light grey shale (Sample 95) when tested in the stationary furnace proved to be a good bloater and to have a wide vitrification range. A well-rounded, well-bloated, product was obtained in the rotary kiln at an average kiln temperature of 1975°F. Agglomeration of the charge started at about 2000°F. There was not enough material for the determination of the physical properties of the product other than the bulk density which as determined by graduate measured 43 lb./cu. ft. The bentonitic shale (Sample 96) and the upper three shale beds represented by Sample 97 proved to be poor bloaters with very narrow vitrification ranges. No rotary kiln tests were made on these materials. As to quality of product the only material from this location having possibilities is the five-foot shale bed represented by Sample 95. However, the amount of overburden and the deposit's location with respect to transportation do not make the occurrence very attractive economically.

A large tonnage of burnt shale is lying on the waste dump of the now inoperative Commerce Coal mine located on the N.E. $\frac{1}{4}$ sec. 12, tp. 10, r. 22, W. 4, approximately 15 miles by rail north of Lethbridge on the Coalhurst-Turin branch of the Canadian Pacific Railway. A grab sample (98) was taken of this material. In the stationary furnace, this shale proved to be a poor bloater and was non-uniform. Rotary kiln tests were not considered warranted.

Shale believed to belong to the upper part of the Oldman formation is exposed along Pothole Creek about 15 miles south of Lethbridge on the N.W. $\frac{1}{4}$ sec. 20, tp. 6, r. 21, W. 4. A section measured in the creek bank was as follows:

Boulder clay	1 foot
Reworked shale	2 feet
Light brown, iron-stained shale (Sample 100)	2.5 feet
Green sandy shale to creek level (Sample 99)	3.5 feet

Greater thicknesses of these shales could easily be found where erosion has not been so severe.

The lower sandy shale (Sample 99) showed only fair bloating properties in the stationary furnace and did not give a uniform product. These results were confirmed in the rotary kiln test in which a very poor product was made.

The upper light brown shale (Sample 100) had good bloating properties, was uniform, and had a wide vitrification range. In the rotary kiln a good product was made showing a bulk density of 45 lb./cu. ft. The crushing strength for one inch compaction was very high at 2307 p.s.i. and the product had a low volume expansion at 20 per cent. The average kiln temperature was 2025°F while the temperature at which agglomeration began was 2050°F. As to quality of product this upper shale (Sample 100) is considered to have good possibilities as a lightweight aggregate raw material. With regard to location, the occurrence is three miles from the railway at Welling, 32 miles by railway from Lethbridge and 159 miles by railway from the nearest large market at Calgary. The particular exposure of shale sampled does not offer good prospects as a quarry site but there are other exposures of the same shale in the vicinity that are much more attractive from the mining viewpoint.

TABER

The area around Taber is underlain by beds of the Foremost formation. On l.s.d. 8, sec. 12, tp. 10, r. 17, W. 4, approximately 20 feet of these beds are well exposed in the strip mine of the Southalta Coal Company, Limited.

A geological section measured at the strip mine was as follows:

Sand with boulders at the bottom	12 feet
Dark grey, carbonaceous shale with iron rich streaks (Sample 101)	10 feet
Very sandy, light grey shale	1.5 feet
Soft, grey sandstone	10 feet
Coal	not measured

The stationary furnace tests made on the carbonaceous shale (Sample 101) indicated that it was too non-uniform in firing qualities to warrant rotary kiln tests. Part of the material bloated well showing a wide vitrification range but, due to a high carbon content, most of the material showed very poor bloating under rapid heat treatment.

MEDICINE HAT

Samples were taken of the shales and clays used at the several brick plants in the Medicine Hat area. At the Medicine Hat Brick and Tile Company's pit a section was noted as follows:

Top soil	3 feet
Plastic "gumbo" clay with some glacial pebbles (Sample 104)	30 to 40 feet
Sandy clay	30 feet
Blue clay (Sample 103)	12 to 15 feet
Sandy clay to floor of pit (Sample 102)	20 to 30 feet

The "gumbo" clay (Sample 104) proved to be a good bloating material when subjected to rapid heat treatments in the stationary furnace. A few particles failed to show any bloating. The vitrification range was somewhat narrow and when tested in the rotary kiln there was no evidence of bloating below the temperature at which sticking became serious.

The blue clay (Sample 103) when tested in the stationary furnace also proved to be a good bloater and had a wider vitrification range than the "gumbo" clay. The stationary furnace products showed a slight non-uniformity in the degree of bloating. In the rotary kiln test the retention time was evidently too short as the product showed a volume expansion of only five per cent. The bulk density measured 51 lb./cu. ft. and the crushing strength 1750 p.s.i. As may be seen from these figures the crushing strength-to-weight ratio was good. The important point shown in the rotary kiln test is that the clay is capable of expansion at a temperature below that of 2025°F at which agglomeration started. It is considered that a longer retention time would give a much improved product.

The bottom sandy clay (Sample 102) proved to be a good bloater in the stationary furnace but its vitrification range was too narrow to allow any bloating below the agglomeration temperature of 2140°F when tested in the rotary kiln.

At the pit of Gunderson's Brick and Coal Company, Limited, Redcliffe, the following generalized section was noted:

Glacial clay overburden	10 to 15 feet
Light grey, iron-stained shale with a small amount of interbedded sandstone (Sample 105)	20 to 30 feet

This shale (Sample 105) showed no bloating and only a very slight degree of fusion when fired in the stationary furnace at 2400°F for five minutes. It was thus classed as too refractory.

At the plant of the Redcliffe Pressed Brick Company, Limited, a generalized section of the shale pit was noted as follows:

Boulder clay	25 feet
Sandy shale	8 feet
Sandstone	1 foot
Dark grey, iron-stained shale (Sample 107)	30 feet
Light grey, sandy shale	10 feet
Black, carbonaceous shale to floor of pit (Sample 106)	10 feet

The black carbonaceous shale (Sample 106) proved to be non-uniform in its bloating properties. When fired in the stationary furnace, approximately 50 per cent of the sample showed good bloating qualities with a wide vitrification range. The remainder which was excessively high in carbon content showed poor bloating under the same firing conditions. These results were confirmed in a rotary kiln test.

The dark grey, iron-stained shale (Sample 107) proved to be a good bloater with a medium wide vitrification range. A rotary kiln test made on this material gave a product with a bulk density of 56 lb./cu. ft. and a crushing strength for one inch compaction of 1432 p.s.i. As the volume expansion measured only 10 per cent, it is evident that a longer kiln retention time would be necessary. The average kiln temperature was 2060°F. Close temperature control would also be necessary as serious agglomerating of the charge started at about 2090°F.

At the pit of the Redcliffe Premier Brick Company, Limited, a generalized section was noted as follows:

Boulder clay	15 feet
Sandstone	6 feet
Greyish-green shale to floor of pit (Sample 108)	15 to 20 feet

When tested in the stationary furnace this shale (Sample 108) proved to be non-uniform. Approximately 50 per cent of the sample tested showed poor bloating qualities while the remainder exhibited no evidence of bloating or fusing under the same firing conditions. In view of this non-uniformity a rotary kiln test was not made.

Of the various materials tested from the brick plants at Medicine Hat and Redcliffe none gave much indication of being good raw material for the production of coated lightweight aggregate. The blue clay (Sample 103) from the Medicine Hat Brick and Tile Company Limited pit and the dark grey shale (Sample 107) from the pit of the Redcliffe Pressed Brick Company Limited did show favourable properties and definitely warrant further work if a raw material is desired in this area. The "gumbo" clay (Sample 104) and the sandy clay (Sample 102) from the Medicine Hat Brick and Tile Company Limited proved to be excellent bloaters but are not considered to have sufficiently wide vitrification ranges for coated aggregate manufacture. These two materials would be the logical ones for experimental work on the making of a rotary kiln sinter aggregate. The remaining materials tested did not show good possibilities as raw materials for lightweight aggregate.

The Medicine Hat area is centrally located with respect to prairie markets and the presence of natural gas fuel is a further inducement to the establishment of industry in this area.

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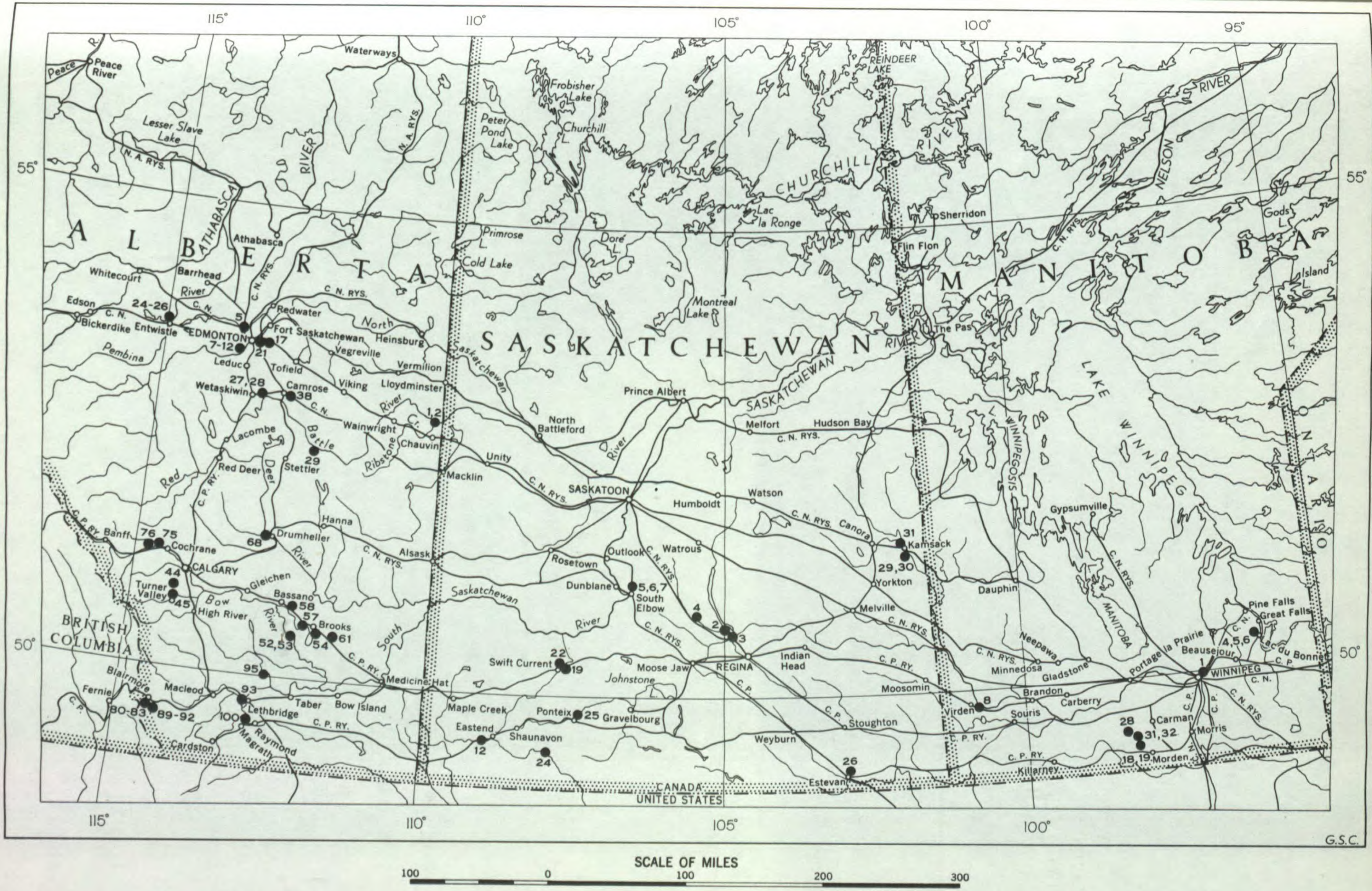

Map of southern areas of Alberta, Saskatchewan and Manitoba showing approximate locations of clays and shales with possibilities for making coated lightweight concrete aggregate.