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DEPARTMENT OF MINES AND TECHNICAL SURVEYS  
MINES BRANCH  
OTTAWA

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

PART V

QUEBEC

by

H. S. Wilson

Industrial Minerals Division

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## PREFACE

The Mines Branch began an investigation in 1949 of sources of clays and shales in Canada which would be suitable for the production of lightweight concrete aggregate. To date, five reports, including the present, have been published on the results of tests of materials from various provinces, the four previous reports being: Part I, Alberta - Memorandum Series No. 117; Part II, Manitoba and Saskatchewan - Memorandum Series No. 120; Part III, Ontario - Memorandum Series No. 121; and Part IV, New Brunswick, Nova Scotia, and Prince Edward Island - Memorandum Series No. 122. Further field work and laboratory tests are necessary before reports can be completed on materials from Newfoundland and British Columbia.

The aim of the laboratory work has been to produce the highest grade of lightweight aggregate, namely a coated aggregate, at the lowest cost by using the raw materials in their natural state. However, many of the materials classed as unsuitable for this purpose have given indications of being satisfactory for the production of sintered aggregate. In the investigations to date, only two samples, both from Quebec, were tested in a sintering machine. Good results were obtained (Page 28). No other sintering tests were made because laboratory work was concentrated on coated-aggregate tests and the size of each sample was too limited to permit additional tests.

For anyone considering the production of a lightweight aggregate, either coated or sintered, the work covered in this and the other reports will help to eliminate the decidedly unfavourable materials and indicate those which merit further attention.

John Convey,  
Director,  
Mines Branch.

COATED LIGHTWEIGHT CONCRETE AGGREGATE

FROM CANADIAN CLAYS AND SHALES

PART V

QUEBEC

by

H.S. Wilson  
Industrial Minerals Division

INTRODUCTION

by

J.G. Matthews\*

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

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\* Those sections of the report preceding the section on Clays and Shales in Quebec were prepared by J.G. Matthews who left the Government Service in May, 1952.

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. The rotary kiln process for producing a sinter type aggregate 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, and as a result 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 -1/2" + 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 bloomers 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.

#### Rotary Kiln Tests

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.

Based on the results of the stationary-furnace and rotary-kiln tests the materials were classified into five groups, as follows\*:-

1. Materials considered suitable for coated aggregate production.
2. Materials which are good bloomers 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 bloomers.
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.

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\* The materials from Quebec are classified in the summary table on page 20.

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.

In connection with 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 market, and availability of fuel are discussed, if known, 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. Such treatment, 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  $4-1/2$  inches. A steel plunger,  $1-31/32$  inches in diameter, was used to apply pressure to the aggregate in a Carver Hydraulic Press and the amount necessary to give a compaction of 1 inch was noted. 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 a product if the result is considered along with the weight of the product. Since weight and strength vary directly, the ratio crushing strength to weight gives a better method of evaluation.

The volume expansion of the product was determined simply by measuring the volume of the 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<sup>(1)</sup> 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<sup>(2)</sup> 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<sup>(3)</sup> considered that the cases which caused bloating when the clay or shale had reached the vitrified condition might have consisted 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 regarded expansion, caused by entrapped gases in a semi-viscous body, as due to two causes:

1. Improper oxidation resulting from insufficient heating time at temperatures below the vitrification range, where the gases were chiefly formed from the carbon, sulphur, and carbonates.

2. Decomposition of contained material during and above the vitrification temperature, the most common material being calcium sulphate which produced sulphur dioxide or trioxide.

Bleininger and Montgomery<sup>(4)</sup> 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<sup>(5)</sup> 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<sup>(6)</sup> showed that not all the sulphur was evolved at low temperatures but that complex compounds of sulphur, such as "ferrous sulpho-silicates" 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<sup>(7)</sup> 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<sup>(8)</sup> heated various clays in a tube furnace and determined quantitatively the gases evolved during bloating. They also determined the effects on bloating of variations in 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<sup>(9)</sup> 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<sup>(10)</sup> 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 bloomers and non-bloomers, 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<sup>(1)</sup> 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 bloomers 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 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 were 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 bloating time given the materials of high carbon content, only a thin surface coating of the particles showed any oxidation or bloating.

Some of the materials classed as poor bloomers would very probably be good bloomers, or be found suitable for coated aggregate manufacture, if the heating time were long enough to remove some of the excess carbon. The effect on bloating when excess carbon was removed by prolonged preheating, before subjection to bloating tests, is illustrated in Figure I, page 14. The decided improvement in the interior structure of the particles is not shown. When a material, high in combustible carbon, is not preheated, the product expands by the swelling of the combustibles rather than by 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 to be representative of their classification as poor bloomers.

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

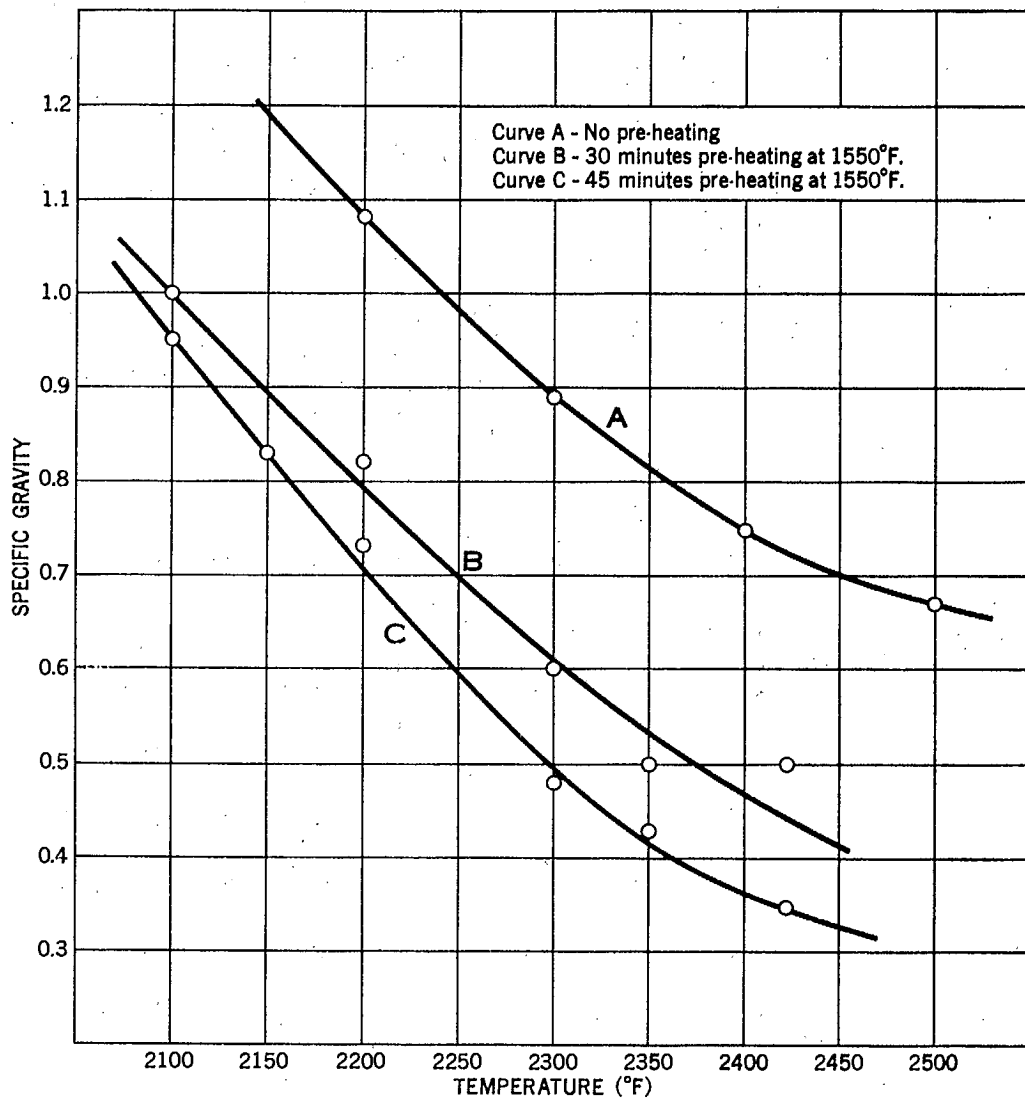


Figure 1 - Effect of preheating upon the specific gravity of bloated specimens of shale high in combustible carbon.

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.

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, page 16, 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

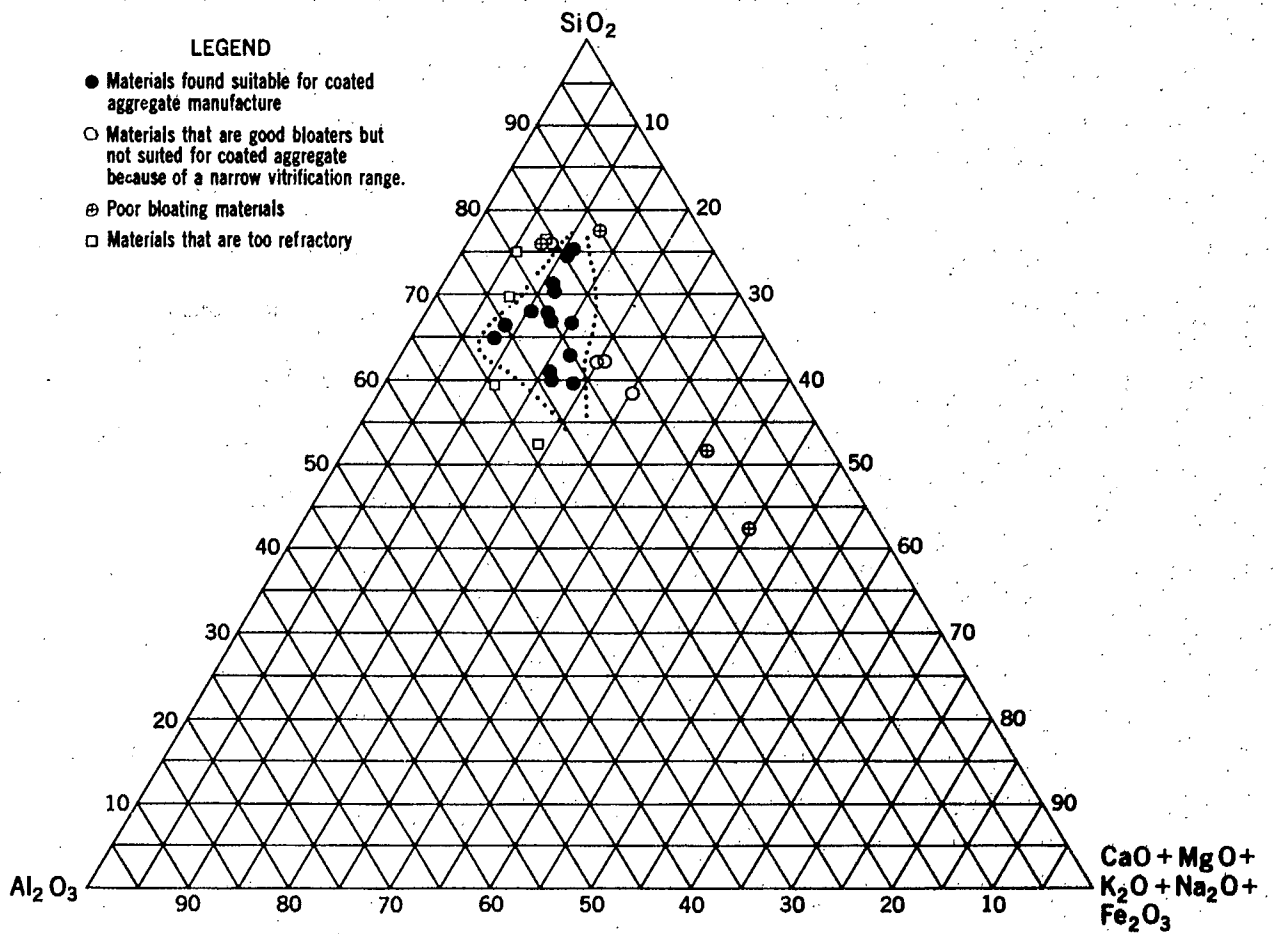


Figure 2 - Composition diagram of major oxides in clays and shales showing proportions required to produce coated aggregate. Dotted line represents approximate limits of materials suited for coated aggregate.

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 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, page 18, 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

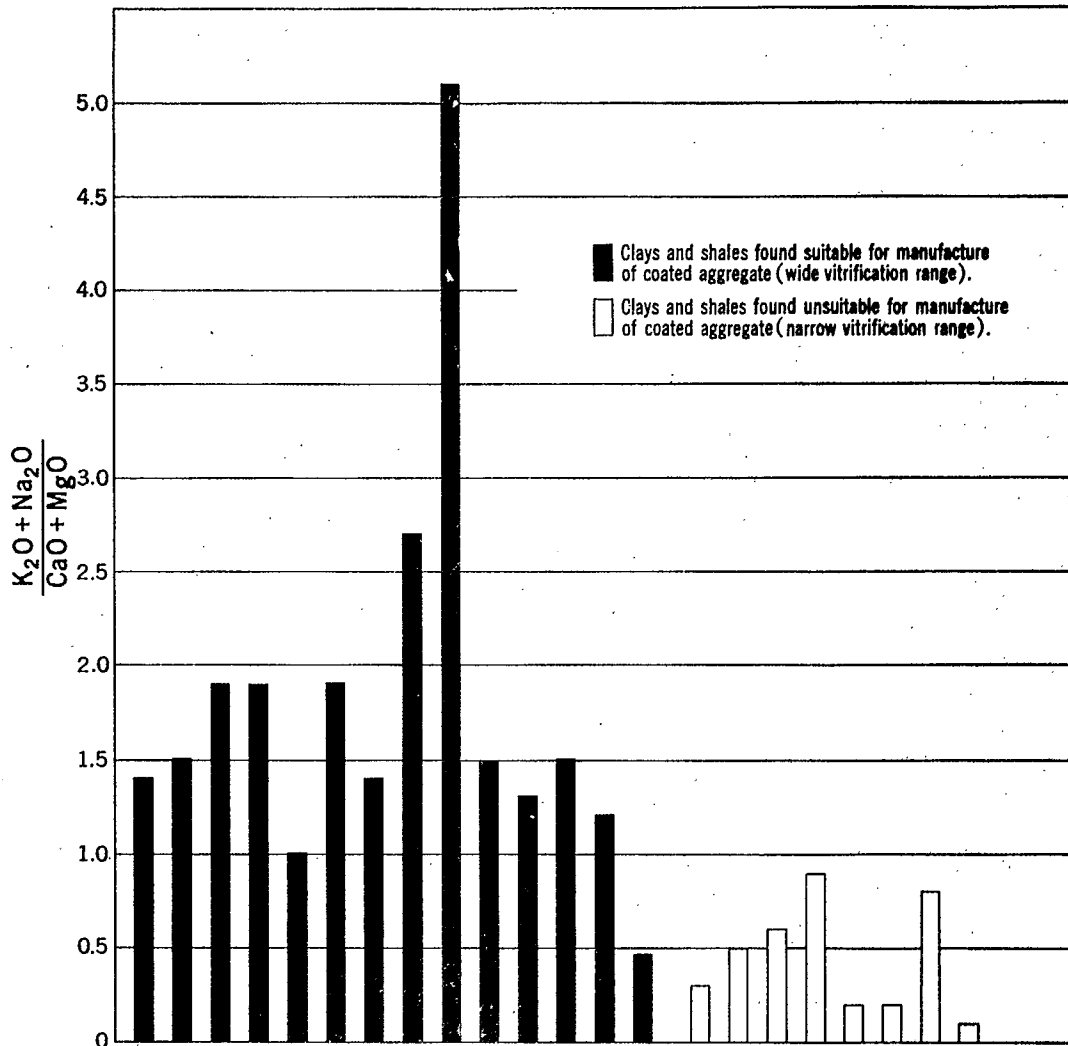


Figure 3 - Relationship of type of fluxes in clays and shales to width of vitrification range.

still be 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.

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, page 16, and an excess of the  $K_2O + Na_2O$  fluxes over the  $CaO + MgO$  fluxes as illustrated in Figure 3, page 18.



Figure 4 - Summary of Lightweight Aggregate Test Results - Quebec

Materials having good possibilities for coated lightweight aggregate		Materials that are good bloomers but are not considered suitable for coated aggregate manufacture because of sticking and agglomerating characteristics		Materials that are poor bloomers		Materials that are too refractory (show no bloating or fusion when fired in stationary kiln at 2400°F for 5 minutes)		Materials that are too non-uniform in bloating qualities	
Location	Sample No.	Location	Sample No.	Location	Sample No.	Location	Sample No.	Location	Sample No.
Delson	7	Hull	1	Montreal	3	Cap Sante	20	Aylmer	2
Laprairie	9	Delson	8	Lakeside	5,6	Neuville	21	L'Epiphanie	4
Chambly	10	St. Johns	12	Ste. Monique	14,15	East Broughton	37	Lévis	26
St. Johns	11	Nicolet	16	Bécancour	17	Ascot Corner	40	Beaumont	28,29
Pierreville	13	Bécancour	18	Quebec	22	Hereford Tsp.	45,46	St. Charles	31
Quebec	23	Deschailions	19	St. Charles	30			Beauce Jct.	33
East Angus	39	Quebec	24,25	St. Joseph	35			St. Joseph	34
Richmond	50	Beaumont	27	Chartierville	43			Deauville	47
Farnham	52	Scott Jct.	32	Sherbrooke	44			Massawippi	48
		St. Joseph	36					Richmond	51
		East Angus	38					Shawinigan Falls	53
		Ascot Corner	41,42						
		Windsor Mills	49						

CLAYS AND SHALES IN QUEBEC

General Distribution

Although Quebec is the largest province in Canada, the areas in which clays and shales are found are comparatively limited. The principal area is in the St. Lawrence River Valley, mainly south of the river.

The various shale formations occurring in this area are all of Palaeozoic age, mainly of the Ordovician period but some in the Eastern Townships are Devonian.

The Sillery formation is mainly south of the St. Lawrence River between Sherbrooke and Rivière-du-Loup. It also occurs on the Island of Orleans and west of Quebec City along the north bank of the river. This shale is usually red but in places ranges from red to black and may contain strata of sandstone.

The Lévis formation is limited to an occurrence in the vicinity of Lévis on the south bank of the St. Lawrence River. It is a relatively hard shale approaching slate in appearance.

The Utica-Lorraine formation is the most extensive shale formation in Quebec. It underlies the St. Lawrence River valley from Montreal to Quebec, on both sides of the river. It also occurs on the south shore of the Gulf of St. Lawrence extending almost the full length of the Gaspé peninsula. The lower member, Utica shale, is more carbonaceous and less sandy than the Lorraine and in places contains bands of limestone, whereas the Lorraine shale in places includes bands of sandstone.

The Medina formation is of Silurian period and outcrops in the vicinity of Nicolet. It is a reddish shale and may contain bands of sandstone.

During the Pleistocene or Post-Tertiary period clays were laid down in southern Quebec and also in the Lake St. John area. They are stratified and in some places contain narrow bands of sand or silt. The clays are basically grey to black, but where oxidation has taken place they are brown.

The extent of this oxidation varies, depending upon the area of outcrop and the amount of overburden covering the deposit.

### Location, Description, and Test Results

Fifty-three samples from forty-nine localities were tested. Nine of the samples appeared to have good possibilities as raw materials for a coated type of aggregate; fifteen showed good bloating characteristics but, due to agglomeration at the bloating temperature, were not considered suitable for coated aggregate; eleven were poor bloomers; six were too refractory; and twelve were not sufficiently uniform.

The price of lightweight aggregate is low in relation to its weight thus making it necessary to keep transportation costs to a minimum. Sampling, therefore, was restricted mainly to the areas surrounding Montreal, Quebec, Sherbrooke, and Trois-Rivières.

Descriptions of the occurrences sampled and the results of the laboratory tests follow.

#### Hull

Canada Cement Company Limited at Hull uses a blue Champlain clay in the manufacture of Portland cement, obtaining the clay from a deposit adjacent to the plant. A sample (Sample 1), from this deposit when tested in the stationary kiln, showed too short a vitrification range to be used for coated lightweight aggregate. The bloating appeared to be fairly good above the agglomerating temperature, and it thus has possibilities as a material for a sinter process.

#### Aylmer

A sample (Sample 2) was taken from an outcrop of a shaly limestone at Aylmer, 5 miles west of Hull. This material was quite high in lime. It was found to be non-uniform when tested in the stationary kiln; portions

bloated well but with a high degree of surface fusion, while the remainder showed no bloating. This non-uniformity makes the material unsuitable as a raw material for lightweight aggregate.

#### Montreal

The Geological Survey of Canada submitted a sample (Sample 3) of Leda clay from Montreal. It was found to be a poor bloater with a very narrow vitrification range. When tested in the rotary kiln, there was no expansion below the agglomerating temperature. It is doubtful if this clay would be of much value in its natural state.

#### L'Epiphanie

A deposit of grey calcareous clay (Sample 4) outcrops on the east bank of the L'Achigan River, 200 yards below the railway bridge near L'Epiphanie, 30 miles northeast of Montreal. The deposit does not appear to be extensive but has a visible thickness of 15 feet overlain by 10 feet of stoney clay. The clay when tested did not prove to be sufficiently uniform to be of much value as a raw material for lightweight aggregate.

#### Lakeside

Montreal Terra Cotta Limited operates a structural tile plant at Lakeside (Pointe Claire). The raw material is a Pleistocene clay, a portion of which has been oxidized to a brownish color. Both the unaltered grey clay (Sample 5), and the brown clay (Sample 6) were found to be poor bloomers with narrow vitrification ranges when tested in the stationary kiln. Rotary kiln tests were considered unwarranted.

#### Delson

The Laprairie Company's plant at Delson, 15 miles south of Montreal, uses an oxidized Pleistocene clay (Sample 7), and Utica-Lorraine shale (Sample 8) in the manufacture of brick and structural tile. When fired at 2,000 to 2,050°F in the rotary kiln, Sample 7 bloated very well, the

expansion being 100 per cent. The product had a bulk density of 36 lb./cu. ft. and a crushing strength for one inch compaction of 1,360 lb./sq. in. This clay seems quite promising as a raw material for a coated type of aggregate.

Sample 8 proved to have too short a vitrification range to be used for a coated aggregate, but it might have possibilities for the sintering process. It bloated quite well in the stationary kiln, but agglomeration occurred at the bloating temperature. Rotary kiln tests were not made.

#### Laprairie

The Laprairie Company also operates a brick plant at Laprairie, 20 miles southeast of Montreal. A large deposit of Utica-Lorraine shale is the raw material used in the making of brick. This shale (Sample 9) has good bloating qualities which seem to suit it for a coated type of aggregate. When fired at 2,100 to 2,150°F in the rotary kiln, it gave an aggregate having a bulk density of 37 lb./cu. ft. and a crushing strength of 1,440 lb./sq. in. The expansion was 115 per cent.

#### Chambly

An outcrop of Utica-Lorraine shale appears on the west bank of the Richelieu River, close to the hydro dam at Chambly, 20 miles east of Montreal. There is 15 feet of shale above water level, topped by 3 feet of overburden. This shale (Sample 10) gave good results when fired in the rotary kiln. It expanded 80 per cent when fired at 2,100 to 2,130°F. The aggregate had a bulk density of 45 lb./cu. ft. and a crushing strength of 1,510 lb./sq. in.

#### St. Johns

Standard Clay Products Limited at St. Johns uses a Pleistocene clay in the manufacture of salt-glazed sewer pipe. The deposit, which covers several acres, is overlain by 2 feet of top soil. There are 3 feet

of oxidized clay (Sample 11) above an almost unlimited quantity of the original grey clay (Sample 12).

Sample 11 exhibited good bloating characteristics when tested in the rotary kiln. The aggregate produced from this test had a bulk density of 49 lb./cu. ft. and a crushing strength of 2,390 lb./sq. in. The material expanded 35 per cent at a firing temperature of 2,000 to 2,050°F.

Sample 12 was found to be unsuitable for a coated type of aggregate as it expanded only 5 per cent before it began to agglomerate when tested in the rotary kiln. Stationary kiln tests however showed it bloated quite well above that temperature (2,100°F).

#### Pierreville

Both banks of the St. Francois River, 1-1/2 miles south of Pierreville, 20 miles east of Sorel, show extensive deposits of Pleistocene clay. Sample 13 was taken from the west bank of the river, where only the oxidized clay was found near the surface. Grey Pleistocene clay would no doubt be found further down in the deposit. The river bank at that point was about 50 feet in height, and the clay appeared to extend the full height of the bank. It bloated quite well when tested in the rotary kiln at 2,000 to 2,050°F. The volume expansion was 45 per cent giving an aggregate having a bulk density of 46 lb./cu. ft. and a crushing strength of 1,250 lb./sq. in.

#### Ste. Monique

A deposit of Medina shale was exposed along the Nicolet River at Ste. Monique, 7 miles southeast of Nicolet. It is a moderately hard, plastic, red shale containing a few narrow bands of green shale. Sample 14 was taken near river level, 125 yards upstream from the highway bridge over the river. At that point there is 8 feet of sand overlying 6 feet of shale. Sample 15 was taken from a 12-foot outcrop covered by 6 feet of sand. This outcrop extended 200 yards along the river, starting 600 yards

upstream from the highway bridge. Both of these samples bloated only slightly when tested in the stationary kiln. This poor bloating quality eliminates them as possible raw materials for lightweight aggregate.

#### Nicolet

Highway cuts through a series of low hills along Highway 3, west of Nicolet, showed Pleistocene clay to be present. Sample 16 was taken from such a cut, 6-1/2 miles west of Nicolet. A trench one foot in depth showed the clay to be oxidized the full extent of the 12-foot face. Further back in the deposit, the clay would probably be the unaltered grey material. That was not investigated. The sample taken was an average of the 12-foot face of the outcrop. Stationary kiln tests showed that the clay did not bloat uniformly below the agglomerating temperature. At higher temperatures, the bloating was good. As this clay would not be suitable for a coated type of aggregate, rotary kiln tests were not made.

#### Bécancour

Two samples, 17 and 18, were taken from deposits of red Medina shale along the banks of the Bécancour River, 2 miles south of the town of Bécancour, 18 miles east of Nicolet. Sample 17, which was from the west bank of the river, was from 10 feet of shale covered by 5 feet of overburden. This shale gave fair results from the stationary kiln tests, but tests in the rotary kiln were disappointing; expansion was only 5 per cent, which is insufficient to produce a good aggregate. Bloating above the temperature where agglomeration occurs might be sufficient to produce a good sintered aggregate.

The deposit on the east bank of the river varied up to 15 feet in depth with 3 feet of soil on top. This shale (Sample 18) was non-uniform below the agglomerating temperature when tested in the stationary kiln. Above that temperature it seemed to be quite good. Due to these characteristics, the shale may have possibilities as a sintered type of aggregate, but not as a coated type.

### Deschaillons

The Pleistocene clay along the south bank of the St. Lawrence River at Deschaillons is the material used by Montreal Terra Cotta Limited in the manufacture of structural tile. It is a blue-grey clay containing a few bands of sand, principally in the lower portion of the deposit which has a depth of about 25 feet. Sample 19 was a grab sample of this clay. In the stationary kiln tests, good bloating was achieved only above the temperature where the particles began to agglomerate.

### Cap Santé

A slaty type of Utica-Lorraine shale extends along the north bank of the St. Lawrence River from Quebec south to Portneuf. It is quite flakey and of medium hardness. Sample 20 was taken from an outcrop along Highway 2,  $1\frac{3}{4}$  miles west of Cap Santé. At that point, there were 15 feet of shale exposed with one foot of top soil. This shale is quite high in free carbon, as was shown when the particles ignited on being placed in the stationary kiln. Due to the high carbon content, this shale did not bloat within an economical temperature.

### Neuville

Sample 21 which was similar in appearance to Sample 20, was taken from a 5-foot outcrop along the highway just east of Neuville. This shale was also too refractory as a result of its high carbon content and no bloating occurred when it was fired in the stationary kiln.

### Quebec

At Wolfe's Cove, Quebec, Utica-Lorraine shale is exposed for a considerable extent. This material (Sample 22) bloated only slightly when fired in the stationary kiln. No further tests were made.

Citadel Brick Limited quarries shale from three deposits in the vicinity of Quebec. Sample 23 was a light-grey shale from Lauzon. It bloated quite well when fired in the rotary kiln at 2,060 to 2,130°F.



The product had a bulk density of 56 lb./cu. ft. and a crushing strength of 2,460 lb./sq. in. However, there is not a sufficient quantity to warrant production of lightweight aggregate.

Sample 24 was a Utica shale from Beauport, 5 miles east of Quebec. Tests in the rotary kiln showed that the shale has a short vitrification range since agglomeration was severe at the bloating temperature. This characteristic, which caused the material to stick to the kiln lining, indicated that the shale would not be suited to the rotary kiln process.

Rotary kiln tests on Sample 25, which was a Utica shale from Boischatel, 10 miles east of Quebec, gave results similar to those from tests on Sample 24.

Using a sintering machine, tests were performed on these two shales (Samples 24 and 25) to determine their adaptabilities to that process. Quite good results were obtained. Powdered coke was used as the fuel in the process. Using 11.5 per cent coke and 3 per cent sawdust with Sample 24, a product having a bulk density of 38 lb./cu. ft. was obtained. Using 15 per cent coke and 3 per cent sawdust with Sample 25, the aggregate produced had a bulk density of 41 lb./cu. ft. These were the best results obtained from several tests in which water, fuel, vacuum, depth of bed, and retention time were varied. From the results, these two shales appear to have good possibilities for the sintering process.

### Lévis

Outcrops of Utica shale, which dip nearly vertically, occur in several locations east of Lévis. The shale is quite flakey and brittle, and contains bands of limestone. Sample 26 was taken from an outcrop along Highway 2, 2-1/2 miles east of the Lévis traffic circle. This shale did not bloat uniformly in the stationary kiln tests. The thin flakes did not bloat, whereas the thicker sections bloated fairly well. Rotary kiln tests were not warranted.

Beaumont

Samples 27 and 28 came from a steeply dipping outcrop of Sillery shale in a cut on Highway 2, 1/2 mile west of Beaumont, 7 miles east of Lauzon. The strata of this outcrop varied considerably in hardness. The outcrop extended for 20 feet along the highway, and was exposed to a depth of 8 feet.

Sample 27 was taken from the eastern half of this outcrop. In the stationary kiln tests, bloating was good only above agglomerating temperature.

Sample 28 was from the western half of the outcrop. The bloating of this material was not sufficiently uniform when tested in the stationary kiln to warrant rotary kiln tests.

Sample 27 shows more promise for the sinter process than for the coated aggregate process and, in spite of the western portion of the outcrop showing non-uniformity, the deposit might be worked successfully if it is sufficiently extensive.

One-half mile south of the junction of Highways 2 and 25A, 2 miles east of Beaumont, a mixture of weathered red shale, sand, and small stone particles was exposed to a depth of at least 5 feet in an open pit. A sample of this material (Sample 29) was passed over a 20-mesh screen prior to testing, to remove the sand. In the stationary kiln tests, the shale particles bloated well, but the stones did not. The non-uniformity of this material did not warrant rotary kiln tests.

St. Charles

Sample 30 was a grab sample of an unconsolidated red shale from a ditch along Highway 25A, just south of St. Charles. This material possessed almost no plasticity, and consequently was difficult to pelletize. Only very slight bloating resulted from firing in the stationary kiln. No further tests were performed.

A sewer excavation on the south edge of St. Charles exposed a deposit of Utica-Lorraine shale, the extent of which is not known. Sample 31 was a grab sample of that shale. At the best, only medium bloating was achieved in the stationary kiln tests, and the degree of bloating was not uniform. These poor bloating characteristics eliminated this shale from further consideration.

#### Scott Junction

La Brique de Scott, Enrg., of Scott Junction, 25 miles south of Quebec, produces brick and tile from a deposit of Pleistocene clay. The pit is at present opened to a depth of about 12 feet. The top 4 feet of the deposit is brown oxidized clay, the remainder is unaltered grey clay. Sample 32 was a grab sample of the brown and grey clays mixed in approximately equal proportions. It was fired in the rotary kiln at 2,050 to 2,100°F. Agglomeration began at 2,100°F. Below that temperature, the expansion was 15 per cent, giving a product having a bulk density of 60 lb./cu. ft. and a crushing strength of 2,460 lb./sq. in. This aggregate has too high a bulk density, but if the clay were fired above the agglomerating temperature, the expansion would possibly be greater than noted. Tests on other Pleistocene clays have shown that the oxidized portion was more suited to the coated type of aggregate than was the unoxidized clay. That may also hold true for this clay, but no tests were performed to confirm that possibility.

#### Beauce Junction

Sample 33 was a black, highly compacted fissile slate from the Beauce County Quarry at Beauce Junction, 5 miles north of St. Joseph. This material was at one time used for roofing slate. The fusion of this slate was not sufficiently uniform to be suited to lightweight aggregate production. Some particles bloated well, while others were completely fused.

St. Joseph

Samples of three clays from this locality were tested. Two (Samples 34 and 35) were red-burning clays used by Syndicat des Ceramistes Paysans de la Beauce. Sample 34 did not bloat uniformly when fired in the stationary kiln. Sample 35 was found to be a poor bloater. Sample 36 was from an outcrop of oxidized Pleistocene clay 6 feet in depth, on Highway 23 and 28, one mile south of the town. Stationary kiln tests showed this clay to be a good bloater, but only above the temperature where agglomeration commenced. Of the three samples, only Sample 36 shows any promise as a suitable raw material. It could not be used to produce a coated type of aggregate, but it might be used in the sintering process.

East Broughton Station

A sample of black, carbonaceous, slaty shale (Sample 37) was submitted for testing, from East Broughton Station, 10 miles northeast of Thetford Mines. It did not bloat when tested in the stationary kiln. This was probably due to the high carbon content.

East Angus

Two samples (38 and 39) were taken from the property of East Angus Brick and Tile, Reg'd. Sample 38 was a grab sample of grey Pleistocene clay. When tested in the stationary kiln, it bloated poorly below the agglomerating temperature. Above that temperature it bloated well. Sample 39, which was from the oxidized portion of the clay deposit, bloated well in the rotary kiln when fired at 2,100 to 2,150°F. The resulting aggregate had a bulk density of 33 lb./cu. ft. and a crushing strength of 1,590 lb./sq. in. This material shows quite good promise as a source of coated lightweight aggregate.

Ascot Corner

Quite extensive outcrops of Pleistocene clay occur at Ascot Corner,

7 miles east of Sherbrooke. Sample 40 was the brown oxidized clay used by a former brick plant. This clay bloated well when tested in the stationary kiln, but only at 2,500°F. which is rather high for commercial production. Two samples (41 and 42) from an outcrop of clay along the highway, just west of the bridge over the St. Francis River, might be suitable for a sintered type of aggregate. Both the brown and grey clays bloated only slightly below the agglomerating temperature, but above that temperature bloating was good.

#### Chartierville

A highly kaolinized clay (Sample 43) formed from an altered dioritic dyke at Chartierville, 50 miles east of Sherbrooke, was submitted for testing. Stationary kiln tests showed this material to be a poor bloater. No rotary kiln tests were made.

#### Sherbrooke

This clay (Sample 44) was similar to that which came from Chartierville in that it was an altered diorite. It too was found to be a poor bloater.

#### Hereford Township, Compton County

Samples 45 and 46 were also altered dioritic material from Lot 21, Concession 6, Hereford Township, Compton County. Sample 45 was highly kaolinized clay, and Sample 46 was partially kaolinized. Neither clay was tested in the rotary kiln, as they did not bloat when fired in the stationary kiln.

#### Deauville

Sample 47 was argillite, or partially indurated slate-like material, from Deauville, 10 miles southwest of Sherbrooke. Only stationary kiln tests were performed as the bloating was not sufficiently uniform to warrant rotary kiln tests.

### Massawippi

A sample of mudstone, or argillaceous sandstone (Sample 48), was submitted from Massawippi, 25 miles southwest of Sherbrooke. When tested in the stationary kiln, the fusion range of this material was not sufficiently uniform, to make it of any value.

### Windsor Mills

Oxidized Pleistocene clay outcrops in several places in the vicinity of Windsor Mills, 15 miles north of Sherbrooke. Sample 49 was taken from an outcrop one mile north of the town, beside highway 5. The clay is exposed to a depth of 10 feet and the deposit seems fairly extensive. Stationary kiln tests showed this clay to be a fairly good bloater. However, tests in the rotary kiln indicated that bloating below the agglomerating temperature is only slight. This eliminates it as a possible raw material for a coated type of aggregate.

### Richmond

A small brick plant at Richmond, 25 miles north of Sherbrooke, produces brick by the soft-mud process. The material used is dense, black, plastic clay. The deposit, which is covered by 4 feet of sandy brown clay, has been opened to a depth of 4 feet. From the tests, this black clay (Sample 50) appears quite promising for a coated type of aggregate. The product from the rotary kiln test had a bulk density of 44 lb./cu. ft., and a crushing strength of 1,115 lb./sq. ft. The expansion was 30 per cent, and the firing temperature was 2,000 to 2,070°F.

Sample 51 came from a three-foot outcrop of oxidized Pleistocene clay, 3 miles south of Richmond, along Highway 5. This clay, which was overlain by 2 feet of sand, appeared to cover a fairly extensive area. Sand was also found below the clay. The clay does not appear to be of much value, as it was non-uniform when tested in the stationary kiln.

Farnham

Along the west bank of the Yamaska River, at the north edge of the town of Farnham, a light-colored, sandy clay (Sample 52) outcrops to a depth of 12 feet. There is very little overburden. The clay bloated well when tested in the rotary kiln, but the strength of the product was quite low. It expanded 65 per cent when fired at 2,100 to 2,150°F giving a product having a bulk density of 44 lb./cu. ft. and a crushing strength of 640 lb./sq. in.

Shawinigan Falls

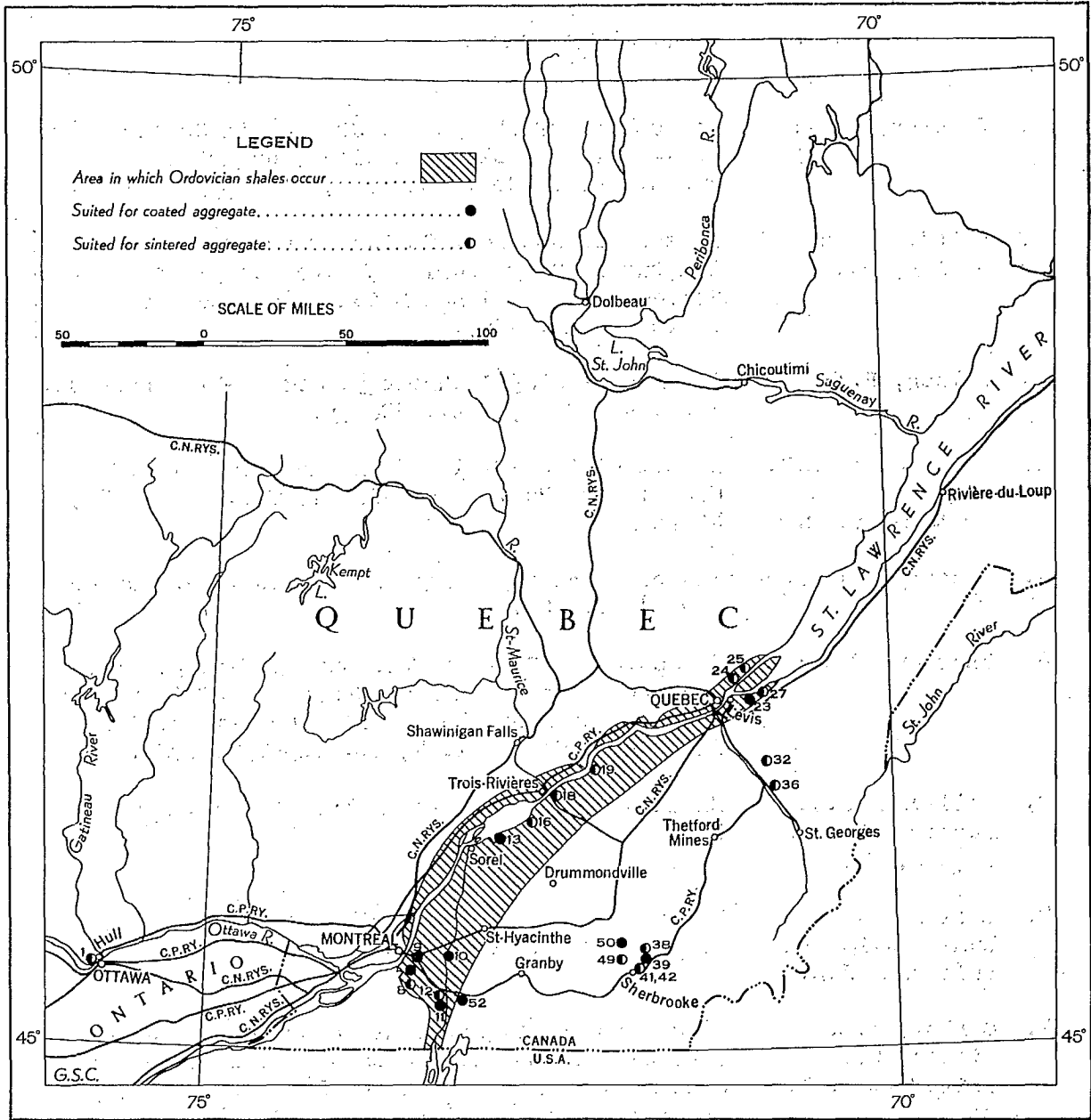
A soft, grey, limey clay (Sample 53) from Shawinigan Falls, which was submitted for testing, proved to be much too high in lime to be of any value. It did not bloat, and mainly burned to a white powder.

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Map of southern Quebec showing approximate locations of clays and shales suited for coated aggregate and those unsuited due to agglomeration.

