MINERALS

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT

MANITOBA FELDSPAR PRODUCT

EVALUATION & MARKET STUDY

SUBMITTED TO:

PROJECT MANAGEMENT AUTHORITY

Mineral Policy Sector, EMR

Ottawa, Ontario

by

AGRICOLA MINERALIA

March 1986

Canada

Manitoba

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EXECUTIVE SUMMARY

ES.1 Background

This report presents the technical evaluation of a potential feldspar byproduct from Manitoba and a market feasibility study for the product grades producible from it. The work was done by Agricola Mineralia, an industrial minerals consulting firm, under a Federal Department of Supply and Services contract. The proposed development is a 75 ton-a-day plant which would produce three product grades: a 40 mesh glass grade; and 200 mesh and 325 mesh ceramic grades.

ES.2 Results

ES.2.1 Technical

A 100 kg representative sample from the ore was laboratory milled into three product grades and chemical analyses and fusion tests were done. The feldspar was found to contain 1.3 per cent rubidium oxide. Theoretical consideration suggested the presence of rubidium would enhance the properties of K-feldspar in its most important end use, high voltage electrical insulators.

In the interests of expediency and economy, glass melt tests only were done. From these tests the feldspar's properties in ordinary and specialty glass and ceramics could be derived. In the soda lime glass a 6 per cent increase in electrical resistivity, attributable to rubidium, was noted. This effect would be multiplied in insulator ceramics where as much as eight times more feldspar is used than in glass. The tests indicated that Rb-feldspar should serve adequately in most other glass and ceramic products.

ES.2.2 Economics

ES.2.2.1 General

Feldspar is the most abundant compound in the earth's crust and, as such, no shortage is possible. This fact gives rise to a general localization of markets, the perimeter of which is decided mainly by competitive freight costs from the various mines. Entry and success of a new supplier require favourable costs, freight advantages and high quality material.

The market picture is fairly complex involving a variety of competing feldspathic materials including Na-feldspar, K-feldspar, nepheline syenite, mixed feldspars, and quartz-feldspar sands, both natural and byproduct of other mineral production.

The glass industry in general can use the whole range of feldspathic materials and chooses on the basis of cost among materials of acceptable iron content. At the other extreme, high voltage insulators require high quality K-feldspar only. The rest of the ceramic industry lies somewhere in between, although, through research, this group has been learning to make do with the cheapest.

ES.2.2.2 North American Demand

Of a total 1.2 million tonnes of feldspathic materials (feldspar, nepheline syenite, aplite, and feldspar contained in quartz-feldspar mixtures) consumed annually in North America, 68% is used in glass manufacture (container, fibre, flat and other), 28% is for pottery and related ceramics and 4% for porcelain enamel, fillers, abrasives, etc.

No increase in demand is foreseen for feldspar in the glass sector to the end of the century. A sharp decline in feldspar for container glass is expected because of increased recycling, development of thinner-walled containers and loss of markets to plastic containers. This decline will be compensated for, partly by demand growth in fibreglass insulation, and possibly in feldspar fillers that could be used in container plastics.

The effect on feldspar demand arising out of the so-called "ceramic fever" of R and D activity in exotic ceramics is not quantifiable at present. It seems likely, however, that this activity could spill over into all sectors of the ceramic industry.

Under an improving North American economy, the demand for traditional ceramics - earthenware, stoneware, chinaware, sanitaryware, electrical porcelain, wall and floor tile, etc. should improve at the rate of economic growth.

Other feldspar-based products include: porcelain enamel; fillers in rubber, paint and plastics; soaps; scouring powders; welding rod coatings, etc. Of this group fillers, an essentially new use, are expected to enjoy rapid growth in demand, especially for plastics.

ES.2.2.3 Prices

Prices for feldspathic materials in the North American market are around $US 25/ton fob. plant for glass grade, $US 34 for 200 mesh from the Carolinas, $US 57 for 270 mesh nepheline syenite and $US 77 for 325 mesh K-feldspar. Prices are recovering from the recessionary low and should return to pre-slump levels over the next year or two. Given the abundance of feldspar resources, however, prices in real terms will be restrained for the balance of this century.

ES.2.2.4 Freight

Freight rates in $Cdn equivalent/ton in bulk, hopper carload lots from Manitoba to U.S. destinations south of the Great Lakes vary from $60 to Chicago to $80 to Rochester, New York. North Carolina rates are $58 to Chicago and $69 to Rochester but the central part (Ohio and Indiana) rates are $40 to $57. Rates from Manitoba to Western Canada are $48 to $70.

ES.3 Market Analysis

The estimated initial market volume obtainable by a Manitoba producer is 27,000 tons a year, well over projected production rates of 22,500 tonnes. Little penetration of the glass market, except in Western Canada, is possible or desirable since the value is low, freights comparatively high, and the market is served by more advantageously located nepheline syenite and aplite. Electrical porcelain insulators are the premium target for Manitoba feldspar and 8,000 tons a year should be an easily attainable volume. Sanitaryware should take 2,000 tons a year; porcelain enamel 2,000 tons; artware, dinnerware and stoneware at least 3,000 tons, ceramic tiles 1,500 tons and miscellaneous markets the remaining 5,000-6,000 tons.

ES.4 Profitability

From an analysis of delivered prices and freight rates to various market points, fob. plant prices for Manitoba feldspar are recommended to be $Cdn 30/ton for glass grade, $Cdn 55/ton for 200 mesh ceramic and $Cdn 75/ton for 325 mesh ceramic. These prices allow for a 10% or greater discount in delivery prices. With acceptance of the product, these prices could ease upward after a year or two and generally rising market prices should further augment fob. prices.

Using production cost estimates derived from information on other mineral producing plants and volumes of each grade indicated by the market survey, an initial net (before-taxes-and-royalties) operating profit of $825,000 for the first full year is calculated. Acceptable price rises in the following few years would increase profit to over $1 million a year.

ES.5 Environment

Protection of personnel from silica-bearing dust is essential in feldspar plants.

ES. 6 Recommendations

A development stage for progression towards production is recommended:

1. production of a few tons of feed.
2. custom milling for plant design and to provide material for customer plant trials.
3. evaluation of tailings for processing.
4. market development and promotion.

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INTRODUCTION

Agricola Mineralia was engaged on contract (DSS File No. 01SF.23230-5-0160) under the Canada-Manitoba Mineral Development Agreement to undertake an economic feasibility study on feldspar and amblygonite that could be produced as byproducts from a Manitoba mine. Initial production levels are projected to be 75 tons-a-day K-feldspar and about one ton-a-day amblygonite. This report deals exclusively with feldspathic materials. A companion report entitled "A Specialty Materials Research Center for Manitoba" contains findings and outlines opportunities relative to Manitoba amblygonite, feldspar, and other mineral products.

This report presents:

1) the results of the mineralogical, chemical and beneficiation studies and laboratory glass batch trials done by IMD Laboratories Ltd. and Corning Engineering;

2) the feldspathic materials classification, grades and specifications;

3) the economic analysis of North American and Manitoba's reachable markets for feldspathic materials, covering supply competition, end use demand, substitution, prices and freight;

4) the market survey and analysis covering estimated sales volume, methodology and market profile;

5) the netback and profitability based on recommeded fob. prices;

6) the impact on the environment of processing and handling and recommended minimum pollution levels; and

7) a directory of feldspathic mineral consumers, suppliers, distributors and research organizations in North America.

Research and development affecting feldspar demand is discussed in brief in this report along with demand considerations. A fuller treatment is presented in the aforementioned companion report.

The findings of this study are that the feldspar market available to Manitoba is more than adequate to absorb the initial projected byproduct output and that an operating profit of over $800,000/year is achievable. Assuming the technical feasibility of increasing output, there is little doubt that a vigorous market development programme could boost operating profits to $1 million or more annually.

Moreover, the study revealed that the Manitoba feldspar is a unique industrial raw material. It contains in excess of 1.3 per cent rubidium oxide which laboratory studies indicate to be superior to K-feldspar in electrical insulator porcelain and possibly other ceramic and glass applications. For this reason the material's industrial mineral name should reflect this uniqueness and the term Rb-Feldspar is proposed. Commercial acceptance will make this specification a tough one for competition to meet.

CHAPTER I

TERMINOLOGY, GRADES AND SPECIFICATIONS

1.1 Definitions

Although the various feldspars have specific uses, the major markets allow for a wide range of substitution of feldspathic materials. For this reason, all feldspathic materials are included in this section.

Feldspar is the general mineral name for a family of alkali-aluminosilicates which together make up over half the bulk of the earth's crust. They are classified under two main categories - the potash feldspars (K-feldspars or K-spars) and the plagioclase feldspars. The two main K-feldspars are orthoclase and microcline which differ only in crystal structure. Sanadine is a high temperature variety, adularia is a low temperature K-feldspar. Rb-feldspar, a special variety of K-feldspar, contains significant amounts of rubidium oxide. The term Rb-feldspar was coined in the present study.

The plagioclases are a solid solution mix of the two end members albite (Na-feldspar, Na-spar or Soda-spar) and anorthite (Ca-feldspar or lime-feldspar). The various species are defined by the ratio of the two they contain (see the table of feldspar species, Table I). Of the placioclase series only the more sodic members (albite, oligoclase and andesine) are used commercially.

TABLE I

Feldspathic Materials

Species	Composition	Remarks
Potash Feldspars		
Orthoclase	$KAlSi_3O_8$	monoclinic K-feldspar
Microcline	$KAlSi_3O_8$	triclinic K-feldspar
Sanadine	$KAlSi_3O_8$	monoclinic - High T°
Adularia	$KAlSi_3O_8$	mixed crystallography, Low T°
Plagioclase Feldspar	$NaAlSi_3O_8$+ $CaAl_2Si_2O_8$(Ab An)	
Albite (Ab)	0% to 10% An	triclinic Na-feldspar
Oligoclase	10% - 30% An	Albite to Andesine
Andesine	30% - 50% An	used in glass & ceramics
Labradorite	50% - 70% An	Labradorite to Anorthite,
Bytownite	70% - 90%	not used commercially
Anorthite (An)	90% - 100% An	
Perthite	Orthoclase (Or) 50% or more	Exsolution of K-spar and Na-spar in a crystal
Antiperthite	Albite (Ab) 50% or more	
Anorthoclase	$Or_{70}Ab_{30}$ to $Or_{10}Ab_{90}$	Na-K feldspar solid solution. High T° Triclinic
Other Feldspathic Rocks and Mixtures		
Feldspathic sand	approx. 50-50% quartz & mixed feldspars	used mainly in glassmaking
Aplite	Mixed feldspars and minor quartz	used mainly in glassmaking

TABLE I (cont'd)

Alaskite	Feldspar with minor quartz	in the trade may include muscovite granites
Nepheline Syenite	Nepheline, microcline albite mixture	most important substitute for feldspar
Phonolite	a lava equivalent of nepheline syenite	used in making coloured glass bottles
Leucite	$KAlSi_2O_6$	occurs in phonolitic lavas, potentially useful

At elevated temperatures (geologically) Na-feldspars and K-feldspars form a complete solid solution series. Below 600°C there is a gap in the series which results in the exsolution of K-feldspar and Na-feldspar in parallel lamellae. Where K-feldspar is dominant, the mineral is called perthite; where Na-feldspar dominates, antiperthite is the term used.

Other feldspathic raw materials occur as mixtures of feldspar and other minerals in loose sands or whole rock compositions. Feldspathic sands bearing quartz are used directly in glassmaking. Although aplite is defined as a sugary-grained rock of granitic composition having K-feldspar and quartz as almost the only constituents, a rock mined in Virginia and termed aplite is almost wholly composed of andesine feldspar. Alaskite, geologically speaking, is a leucocratic granite composed chiefly of K-feldspar with minor quartz. An "alaskite" mined in North Carolina is more properly termed a muscovite granite because of its mica, oligoclase, microcline and quartz content. Nepheline syenite is a granitic rock having no quartz and is made up of nepheline, microcline and albite with minor magnetite, pyroxene, hornblende and mica. The latter undesirable minerals are removed using a magnetic separation process. The mineral nepheline is a feldspathoid, which is similar to feldspar except for its lower silica content. Phonolite is a lava of nepheline syenite composition which is used in Europe for making wine bottles. Leucite, a feldspathoid analyzing at 21.5% potash, occurs in phonolitic lavas. Although the whole rock is used, leucite could prove to be a valuable K-feldspar substitute were a cheap concentrating technology to be employed.

1.2 Industrial Raw Materials

Specifications for feldspathic materials vary from user to user and must be ascertained as part of the marketing process. It is important to understand, however, that specifications are basically decided by the dominant producers of the raw materials and adopted by the user. Price itself is a part of this picture. The rationale for specifications for the content of colourants such as iron oxides, cobalt and chromium for ceramics and glass is one of perceived aesthetics rather than of engineering excellence. A glass batch running 0.1% Fe_2O_3 would make jars of a durability equal to another of half that iron content but acceptance by the consumer of foodstuffs in greenish jars may not be high. Refractory grains; for example corundum, which will not melt readily with the other ingredients, are specified at a minimum to prevent "seeds" in glass or ceramics. Other specifications relate to the alkalis, alumina and silica content which affect the rate and temperature of melting, fluidity of the melt and engineering properties of the finished product. The following are general specifications in the trade (Table II).

TABLE II

Specifications

A) General

Item	Specifications
K-feldspar	10% or more K_2O
Na-feldspar	7% or more Na_2O
Nepheline Syenite	Na_2O - 10.2%, Fe_2O_3 - less than 0.07%

B) End Use

Item	Specifications		
	Particle Size	Fe_2O_3	Other
Glass			
High quality	-210 + 100 mesh with limit on overgrind		
Clear -		0.05%	Cr, 6ppm; Co. 2ppm;
Flint -		0.07%	Alkalis constant (±0.5%)
Coloured & fibre glass		0.1-0.6%	
2) Ceramics			
Sanitaryware	-200 mesh	0.05%	5% to 14% K_2O
Pottery	-200 mesh	0.05-0.1%	High potash generally
Porcelain	-120+140 mesh	0.05%	Nil garnet, hornblende, tourmaline & mica
Glazes	-200 mesh	0.05%	Both K & Na Feldspars used
Enamel	-200 mesh	0.05%	High K-feldspar
Electrical Porcelain	-200 mesh	0.05%	High K-feldspar
3) Fillers			
(Rubber, plastics paints)	10 microns	0.07%	Nepheline Syenite, could use feldspar

TABLE III

Representative Industrial Grades*

	1	2	3	4	5	6	7**	8	9	10
SiO_2	67.65	67.4	69.5	66.80	66.84	71.40	68.0	60.0	76.0	84.7
Al_2O_3	19.10	18.3	18.0	19.64	18.49	16.5	17.4	23.6	13.9	8.5
Fe_2O_3	0.051	0.09	0.1	-	0.079	0.16	0.043	0.07	na	0.11
CaO	1.70	0.33	-	1.70	0.86	0.07	0.17	0.30	na	0.93
MgO	tr	-	-	tr	-	.008	0.10	0.10	-	0.02
Rb_2O	-	-	-	-	-	-	1.32	-	-	-
K_2O	4.22	10.00	4.80		10.54	8.4	9.49	5.30	3.0	3.0
Na_2O	7.04	3.50	6.90		3.01	3.4	1.78	10.20	4.95	2.0
LOI	0.12	0.53	0.35	0.20	0.16	-	0.70	0.5	na	na
units	30.36	31.80	29.70		32.04	28.30	29.99	39.1	21.85	13.5

1. Feldspar Corp NC-4 200 mesh
2. Feldspar Corp K200 325 mesh (Li byproduct)
3. IMC (Glass grade) 20 mesh
4. IMC Kona F-4 200 mesh
5. Feldspar Corp G200 325 mesh
6. Pacer Corp 200 mesh (Handcobbed K-spar, S. Dakota)
7. Manitoba Rb-Feldspar (prepared sample)
8. Indusmin Ltd. Nepheline Syenite glass grade
9. Feldspar Corp Silispar 200 mesh (quartz-feldspar mix)
10. Idaho - Feldspathic Sand - glass grade

* These are nominal grades, usually a leaway of ½ to 1 per cent allowed either side for major oxides, trace elements not shown.

** Rb_2O is an alkali flux and would be considered part of the sum of total alkalis ($K_2O + Na_2O + Rb_2O$ = 12.59%). Also, it may be treated as K_2O equivalent i.e. ($Rb_2O + K_2O$ = 10.81%). Rb_2O occurs only in no. 7 (1.32%).

It is interesting to compare columns 6 and 7 because Pacer Corp's K-feldspar from Custer, South Dakota is the most direct competition for Manitoba feldspar in virtually all of its markets.

Value comparisons for feldspathic materials are made on the basis of contained units (sum of alumina and the alkalis, see Chapter III, 3.4 Nepheline Syenite/Feldspar Competitive Factors). Rb-feldspar from Manitoba has 30 units per ton compared to 28.3 units for the South Dakota feldspar, which gives the former a 6 per cent premium in value over the latter. The much lower iron content of the Rb-feldspar is an added positive factor. Comparison of column 7 with columns 2 and 5, which are K-feldspar competitors in the Eastern Region, shows Rb-feldspar to be 2 units lower. Since analysis of a quartz-free Rb-K-feldspar would run about 64% SiO_2, it can be seen that the sample carries about 4 per cent free quartz. The free quartz level would have to be reduced by half to produce a product running 32 units. This might be done simply by screening and rejecting a coarse fraction, say 10 to 20 mesh, which would tend to concentrate quartz preferentially because of its greater resistance to grinding. Use of electrostatic separation would be effective but the overall economics would have to be studied.

CHAPTER II

SAMPLE PREPARATION, ANALYSES AND TESTING

2.1 Mineralogical and Beneficiation Studies

A representative sample of approximately 100 Kg was collected from the ore and shipped to IMD Laboratories Ltd. of Toronto, Ontario. The sample was ground and sized into three products: -40 mesh, -200 mesh and -325 mesh, and the feed material was chemically analysed (see Tables IV and V). A heavy mineral concentrate comprising 2.5 per cent by weight of the sample was separated, chemically analyzed (Table V) and subjected to fusion tests.

Chemical analysis of the feed yielded a surprising result. The material runs 1.32 per cent Rb_2O*, almost as much as the soda content, making this a unique feldspar. This finding made necessary further study to ascertain the effect of rubidia on glass/ceramic products. Supplementary testing was done to evaluate the engineering properties of two glass formulations employing this feldspar. Testing procedures and parameters are reported in full in the next section.

* Elsewhere in the deposit the Rb_2O is somewhat higher. Personal Communication: R. Gunter (Manitoba Energy and Mines).

The heavy mineral concentrate, which was expected to be largely lithium minerals, also proved to be unusual. Chemical analysis and x-ray diffraction studies have so far failed to identify a cation comprising 7 per cent of the composition. Fusion tests by IMD Laboratories Ltd. on the heavy mineral fraction, however, did yield a clear, easily fusible glass; a positive result for application in glass and ceramics.

High intensity magnetic separation reduced the iron content marginally.

2.2 Glass Melt Studies

Corning Engineering recommended two glass formulations be made and tested to evaluate the Rb-feldspar. Work done involved the following:

2.2.1 Tests on the Feldspar

1. Semi-quantitative spectrographic analysis
2. Quantitative analysis for Al_2O_3, Fe_2O_3, Na_2O, K_2O, Rb_2O, P_2O_5, F^-, Cl^-, and L.O.I.

TABLE IV

Particle Size Analysis

Screen	-40		-200		-325	
	Wt%	Cum.%	Wt%	Cum%	Wt%	Cum.%
-30, +150	95+	-				
+100			0.02	0.02	tr	tr
-100, +140			0.48	0.50	0.12	0.12
-140, +200			3.75	4.25	0.91	1.03
-200, +270			8.06	12.31	3.51	4.54
-270, +325			5.49	17.80	3.59	8.13
-325, +400			6.17	23.97	4.13	12.26
-400, +500			10.70	34.67	8.75	21.01
-500			65.33	100.00	78.79	99.80

TABLE V

Chemical Analysis

Oxides	Feed %	Feed-Mag%	Heavy min.%	Remarks
SiO_2	68.0		63.7	Feed Trace l.
Al_2O_3	17.4		24.1	Cr 10 ppm; Sr 210 ppm
CaO	0.17		0.58	Y 100 ppm; Zr 10 ppm
MgO	0.10		0.15	Nb 10 ppm; Ba 770 ppm
Na_2O	1.78		0.27	Heavy Minerals
K_2O	9.49		0.39	Total 2.54%
Rb_2O	1.32		0.058	Cr 70 ppm; Sr 20 ppm
Fe_2O_3	0.043	0.036	1.30	Y 10 ppm; Zr 10 ppm
MnO	0.01		0.10	Nb 150 ppm; Ba 170 ppm
TiO_2	0.01		0.05	
P_2O_5	0.45		0.059	6.6% unaccounted for
L.O.I.	0.70		2.05	
Li			0.23	

2.2.2 Tests on Two Glass Types Melted from Batches Containing Rb-Feldspar

1. Batches were weighed, mixed and melted to yield:

   Glass 1: Nominal composition of 55.1% SiO_2; 29.1% PbO;, 8.7% K_2O; 4.0% Na_2O; 2% Al_2O_3; and 0.7% Sb_2O_3.

   Glass 2: Nominal composition of 72.5% SiO_2;, 14.5% Na_2O; 10.7% CaO; 1.8% Al_2O_3; .5% MgO and .4% K_2O.
2. Softening, anneal and strain points, thermal expansion coefficient and density.
3. Volume electrical resistivity to 250°C and 350°C.
4. U.S.P. Powder durability.
5. Liquidus temperature with primary Crystalline Phase Identification.
6. Quantitative analysis of glass for Rb_2O, Na_2O, K_2O, Al_2O_3, Fe_2O_3, and (CaO and MgO in soda lime glass) or (PbO and Sb_2O_3 in lead glass).

Details of the test and procedure are given in Appendix III, summary Tables VI and VII provide chemical analyses of the glasses and their engineering properties.

2.3 Application

Because of time limitations and the high costs of undertaking a study of a variety of ceramic formulations, the glass melts were chosen. Ceramicists can apply the findings to interpret the properties of the feldspar in other products, however.

In ceramics, the feldspar comprises a much higher proportion than in glass melts and the effect of rubidia should be more significant. Na-feldspars have a lower molten viscosity and higher electrical conductivity than K-feldspars. The preference for K-feldspar in high voltage electrical insulators derives from these properties. A higher viscosity in a ceramic body results in a lesser tendency for sagging or warping upon firing, a factor of importance where the ceramic bodies are large, as in the case of electrical insulators. The value of lower electrical conductivity (higher electrical resistivity) is self-evident. In the ceramic trade, the K-feldspar is said to have a lower fluxing action (roughly half) than Na-feldspar. Theoretically a Rb-feldspar phase would have a fluxing action roughly half that of K-feldspar (related to the larger atomic volume of the heavier alkali metals) and an electrical conductivity even lower than that of K-feldspar. In other words, Rb-feldspar would theoretically behave like a super K-feldspar in ceramic and glaze formulations.

Even with the high dilution involved in the glass melt tests conducted by Corning Engineering, the theoretical behaviour anticipated was born out (see Table VII). The DC Volume Electrical Resistivity values for the soda-lime glass containing Manitoba feldspar were higher than the standard values. The resistivity value at 350°C was 5 per cent higher and at 250°C was 6 per cent higher with the Rb-feldspar comprising only 6.8 per cent of the glass batch. For electrical insulators, the feldspar content of the ceramic body is

TABLE VI

Chemical Analysis (%)

	Feldspar	Soda Lime Glass	012 Type Lead Glass
Al_2O_3	16.80	1.65	2.04
Na_2O	1.77	13.2	4.05
K_2O	10.3	0.86	8.37
CaO	-	10.66	-
MgO	-	0.33	-
Sb_2O_3	-	-	0.71
Fe_2O_3	0.084*	0.044	0.031
F-	0.040	-	-
Cl-	0.009	-	-
LOI	0.31	-	-
PbO	-	-	28.92
P_2O_5	0.34	-	-
Rb_2O	1.65*	0.13	0.19
USP III Powder Durability (0.2N H_2SO_4)		7.97 ml	4.81 ml

* Shaking of material in transport may have resulted in some gravimetric separation. Analysis of the small sample taken diverges from the representative analysis of Table IV.

TABLE VII

Physical Properties

Property	Soda Lime Container		012 Lead	
	Typical Values	Test Glass	Typical Values	Test Glass
Softening Point (°C)	724	724	630	642
Anneal Point (°C)	550	552	435	450
Strain Point (°C)	508	507	395	427
Expansion (x 10^{-7}/°C)	89.8	88.7	89.5	90.1
Density (gm/cm^3)	2.50	2.4981	3.05	3.0355
Liquidus ((°C)	980(avg)	975(avg)	760(avg)	none
D C vol, Elect.				
Resist. (250°C)	6.6	6.970	10.1	9.875
(350°C)	5.3	5.555	8.0	7.860

usually about 30 per cent suggesting high performance insulator properties for the Rb-feldspar.

Regarding melt characteristics, little variation from the standard was observed for the soda-lime glass. This may be due to the very high soda-potash ratio (15.33/1) of the batch. The lead glass batch, however, had more Rb-feldsapr (11.3 per cent) than the soda-lime batch (6.8 per cent) and a soda-potash ratio of only 0.48/1. The softening, anneal and strain points of the lead glass were all higher for the Rb-feldspar-containing batch relative to the standard with the only difference in composition being the Rb content. The softening point was 642°C, 12°C above the standard, suggesting that a lesser tendency for sagging or warping of a fired body would result from usage of Rb-feldspar.

Corning Engineering could not say whether television tube makers would welcome the slightly higher glass forming temperatures indicated. However warping or sagging of a finished product is at risk with large items like T.V. tubes and it is conceivable that Rb-feldspar would be an asset here.

CHAPTER III

ECONOMIC ANALYSIS

3.1 Approach

An economic analysis of the feldspar industry is presented in two parts. The first examines the overall North American supply-demand picture outlining its structure, production, end use demand, historical performance, forecasts, substitution trends, pricing practices and the like. The second part analyzes economic factors within the market area reachable from Manitoba. Together these provide the background essential for market development for the feldspar products producible in Manitoba.

3.2 Supply

With feldspar unquestionably the most abundant mineral available to man on earth, the concept of supply is no simple matter. It is defined by the mineral's accessibility to low-cost extraction and beneficiation methods, its chemistry and the potential of its reachable market. Moreover, timing of a feldspar development can also be a factor in the supply picture. Once a plant is established in a market, a potential competition with a similar deposit is pre-empted unless he can produce an equivalent or better product more cheaply and can garner customer confidence in his operation. It can be likened unto the production of liquid air products where, despite the availability of air, only a few companies are engaged in the business.

A further complication in the supply picture is the variety of feldspathic materials competing in the market. The material is acceptable in many end uses in the form of individual pure feldspar species, mixtures of feldspar species with or without quartz and with other minerals which provide alumina and the alkalis such as nepheline and leucite. Moreover, while some end uses, such as glass, may use interchangeably virtually the whole range of feldspathic materials, other uses may specify a high purity feldspar of a given species. An example of this is the requirement for high purity K-feldspar in electrical porcelain for making high voltage insulators.

Sticking to the economic idea of supply as the general availability of a good on short notice, the term applies only to products available from existing plants. And since abundance and low prices tend to localize markets, the North American market as a unit for study is more than adequate in scope for evaluating interaction between producers and potential new producers. Supply for the purposes of this study, then, is the aggregate output of Canadian and United States plants.

3.2.1 Canada - Production

A number of pegmatites in Western Quebec and Eastern Ontario (centred on Perth, Ontario, the type locality for perthite) were worked for feldspar and associated minerals over the past 100 years or more. The last significant operator, International Minerals and Chemicals (Canada) Ltd. (IMC), closed its plant near Buckingham, Quebec in 1972 when competition from nepheline syenite, derived in part from an IMC plant, reduced markets to below 10,000 tonnes annually in Canada. Small independent local producers who had been delivering hand-cobbed, high purity K-feldspar (dental spar) intermittently to the IMC mill, made a few small tonnage deliveries of rough material to customers in the U.S.A. and Sweden after that date. Johnson and Johnson Ltd, of Montreal undertook a feasbility study in the Buckingham area a few years later but today the Canadian feldspar industry is inactive.

Nepheline syenite is composed of a mixture of Na-feldspar (54%), K-feldspar (20%), nepheline (20%) plus the easily removable impurities: mica, pyroxenite, hornblende and magnetite. The stronger fluxing action of nepheline syenite when compared to feldspar, and other factors to be discussed, have made nepheline syenite the preferred source of alumina and the alkalis in glass-making within a market area defined by competitive delivered prices (including a premium for nepheline syenite).

After slow beginnings in the 1930s and 40s, nepheline syenite markets expanded rapidly, displacing feldspar in glassmaking and compatible ceramic uses until saturation of feldspar markets had occurred by 1970. Modest growth in the 1970s is attributable mainly to the development of fine ground paint and filler grades and the recent decline in output was a result of the deep recession beginning in 1981.

Indusmin Limited, a subsidiary of Falconbridge Nickel Mines Limited, is the sole producer of nepheline syenite in Canada since they purchased their competitor's (that of IMC Chemical Group (Canada) Limited operation) in the same Blue Mountain, Ontario deposit in 1985. Combined plant capacity stands at 800,000 tonnes/year with current output near 500,000 tonnes. The deposit is approximately 8 km long by 2.4 km wide and is roughly pear-shaped. Despite the unusual uniformity of composition, careful pit development and blending of ore is practised to maintain consistency over time. The ore is crushed, ground and upgraded using high intensity magnetic separation. Recovery (per cent of product from ore mined) is 80 per cent. A variety of products is produced differing mainly in grain size from 40 mesh (glass) to micronized filler material.

Although nepheline syenites are not uncommon, the required uniformity of composition and amenability to low cost beneficiation appears to be. Outside of Canada, only Norway and, in the last 3 years, Brazil have been able to develop one nepheline syenite deposit each. Nepheline syenites elsewhere in Ontario and in Quebec and British Columbia have been evaluated and found unsuitable. No new deposits are expected to be developed within the North American market in the near future. Nevertheless, Indusmin's operation has excess capacity of 300,000 tonnes/year at present and adequate reserves for further expansion.

3.2.2 Potential Canadian Supplies

In addition to feldspar reserves remaining in previously worked pegmatites and the potential for expanded production of nepheline syenite at Blue Mountain, several other sources exist from which feldspathic materials might be drawn should markets warrant. Nepheline syenites occur in numerous localities in Southern British Columbia (Ice River and Big Bend areas), in the Bancroft, Port Coldwell and other areas in Eastern Ontario. Although these have been examined in the past and found wanting, a metallurgical breakthrough, such as an economic flotation, electrostatic or other process for concentrating nepheline would permit exploitation of the best of these.

Competitiveness in the feldspar industry discourages development of pegmatites from which only feldspars can be produced. Byproduct operations show the most promise. Lithium deposits at Amos, Quebec, formerly in production by Sullivan Mining Group Ltd.; in the Nipigon district of Ontario (Jean Lake Lithium Mines Ltd., Ontario Lithium Company Limited and Big Nama Creek Mines Ltd.); near Lac La Croix east of Fort Frances, Ontario and in Eastern Manitoba, the most important being Tanco's Bernic Lake deposit; all are potential feldspar producers. Lithium pegmatites at Herb Lake, Manitoba and in the Yellowknife - Beaulieu districts, Northwest Territories are too remote from markets.

Feldspathic sands have been examined at Scuzzy Creek, in the Boston Bar area of Southern British Columbia. Here an estimated 1 million tonnes of sand with an oligoclase/quartz ratio of 3 to 1 occurs. An increase in demand for glass sand would rekindle interest in this deposit. Feldspar-silica sand deposits of fair quality occur in stream systems where the entire basins drain only granitic terrain and where Pleistocene glaciation has not contaminated the system. Such resources have been drawn upon in the Western United States and it is likely that many such deposits occur in the Coast Range. Very little potential exists for commercial feldspar deposits on the Great Plains.

3.2.3 The United States - Production

Thirteen companies currently produce feldspathic materials in the United States from 19 deposits using 16 plants. Three companies mine K-feldspar and the remainder produce a mixed feldspar product or feldspar-quartz sand. One mixed feldspar product was derived from aplite. Table VIII shows current producers, plant and products. Output in 1985 was about 640,000 tonnes contained feldspar (feldspar plus that contained in mixtures with quartz). Plant capacity is 850,000 tonnes a year and mining capacity is about double this.

Production of feldspar in the United States dates from 1825 with development of pegmatites in Connecticut, although there is some

TABLE VIII

U.S. Feldspathic Materials Producers (1985)

Company	Plants	Product
Feldspar Corp.	Connecticut Georgia North Carolina Virginia	K-feldspar Feldspar mix from "Alaskite" Aplite feldspar
Indusmin Inc.	North Carolina	mix from Alaskite
International Minerals & Chemicals Corp.	North Carolina	mix from Alaskite
Calspar Inc.	California	K-feldspar
Pacer Corp.	South Dakota	K-feldspar
Foote Mineral Co.	North Carolina	Feldspar, feldspar silica mix co-product
Kings Mountain Mica Co. Inc.	North Carolina	Feldspar, feldspar silica mix co-product
Spartan Minerals Corp.	South Carolina	"
Crystal Silica Co.	California	Feldspar-silica sand
Owens-Illinois Inc.	California	"
Arkhola Sand & Gravel	Oklahama	"
Feldslite Corp.	Oregon	"
Unimin, Corp.	Idaho	"

evidence that native Americans used it in pottery and that samples of feldspar were shipped to Europe in the previous century. Connecticut remained the most important source until early in the present century when North Carolina became the leading producer. Today, North Carolina accounts for about 70 per cent of total United States feldspathic material production, mainly flotation concentrates from "alaskite" and byproduct feldspathic sands from lithium mining. Hand-cobbing from pegmatites, once the only production method, now accounts for a mere 1% of annual production from U.S. operations.

Feldspathic materials, mostly from pegmatites, have been produced from 18 states during this century. Natural feldspathic sands have been developed commercially only in Western North America and current operations in the U.S. are in Oklahoma, California, Idaho, and Oregon. Mixed feldspars from aplite in Virginia are used for glassmaking.

3.2.3.1 North Carolina

Five of the United States' 16 plants operate in North Carolina. Three companies: Feldspar Corp, Indusmin Inc. and International Minerals and Chemical Corp produce flotation concentrates from alaskite of the Spruce Pine district, Mitchell County, in Western North Carolina. The district is about 30 km long and 20 km wide in which occur bodies of coarse grained "alaskite" with irregular masses of pegmatite which are gradational into the alaskite. Large individual feldspar crystals and patches of graphic granite also occur. Early in the history of the area, only the pegmatites were exploited. With the advent of froth flotation, attention was switched to the alaskite. Abundant reserves exist in the Spruce Pine and adjacent districts.

Feldspar and feldspar silica mixtures were produced as byproducts in the Kings Mountain district by two companies. Foote Mineral Co., the world's largest lithium producer, produced a feldspathic byproduct from pegmatites and Kings Mountain Mica Co. Inc. produced byproduct feldspar-silica from its mica operation. The district, a linear belt hosting a great many pegmatites, is 40 km long. Current production in North Carolina is about 420,000 tonnes a year and reserves are adequate to maintain this for many decades.

3.2.3.2 Connecticut

Feldspar Corp. mines zoned pegmatites on the eastern highlands in the Middletown district near the town of Middle Haddam. The district, 22 km by 14 km in area, is underlain by the Boltan schist and Monson gneiss into which are intruded numerous zoned pegmatites. The Strickland deposit, one of the largest, is over 230 m long and 80 m wide. Five zones occur: a thin border zone, plagioclase-quartz-muscovite zone, perthite-graphic granite-quartz plagioclase zone, plagioclase-quartz zone and a quartz-plagioclase core. The ore is basically restricted to the perthite-graphic-granite-bearing zone. Formerly a hand cobbing operation, flotation is now used. Production is currently estimated at 60,000 tonnes a year. Considerable reserves remain in the district.

3.2.3.3 Georgia

The western pegmatite belt through North Carolina and South Carolina extends through northwestern Georgia and into Eastern Alabama. Flotation feldspar is produced in one plant in Georgia operated by Feldspar Corp. Output is currently an estimated 40,000 tonnes a year. Reserves throughout this belt are very large.

3.2.3.4 California

Claspar Inc. produces K-feldspar in the Pala district, San Diego County, California, from pegmatites. Owens-Illinois Inc. and Crystal Silica Co. produce feldspar-silica sand mixtures from unconsolidated sand deposits. Although reserves from sand sources are large, there is a history of environmentalist opposition to the natural sand operations which could curtail their output in the future. Present output of feldspar (pegmatite and contained in sand) is around 40,000 tonnes a year.

3.2.3.5 Oklahoma

The Arkhola Sand and Gravel Co. produces a feldspar-silica sand product from natural sand deposits. Current output is estimated at 30,000 a year.

3.2.3.6 South Carolina

Spartan Minerals Corp, a subsidiary of Lithium Corp of America, produces byproduct feldspar-silica from mill tailings of their lithium operations at Pacolet, Spartanburg County, and from adjacent North Carolina. The Pacolet deposits are the southern extension of the Kings Mountain district in North Carolina. Output is estimated at 20,000 tonnes a year.

3.2.3.7 South Dakota

Pacer Corp operates a grinding and screening plant in the Custer district of South Dakota. Pegmatites containing spodumene and other minerals are mined for K-feldspar which is concentrated by hand cobbing. Output is about 6,000 tonnes a year, considerably down from previous years. Reserves are large, but comparatively expensive hand cobbing methods are unlikely to endure. It is questionable if they would be likely to replace these operations with an expensive concentrator to produce a feldspar main product, especially should a byproduct operation start up in Manitoba.

Pacer Corp also obtains small quantities of dental-spar on an intermittent basis from a pegmatite near Casper, Wyoming.

3.2.3.8 Virginia

Feldspar Corp mines an aplite body near Montpelier, Virginia, a former operation neary Piney River having closed in 1981. They produce a feldspar flotation product of dominantly andesine composition (Na-Ca-Spar). A wide variation in texture and grain size is the result of tectonic granulation of an originally very coarse-grained rock. The intrusion is about 20 km long and up to 4 km wide. Production, once over 200,000 tons, has declined over the past few years and output is estimated to be below 100,000 tonnes a year. The entire output is used in glassmaking.

3.2.3.9 Idaho

A feldspathic sand analyzing 2% Na_2O, 3% K_2O and 8.5% Al_2O_3 is produced near Emmett, in southern Idaho and is sold to the glass industry, principally in Washington State. Output is estimated at 40,000 tonnes (containing close to 20,000 tonnes of feldspar).

3.2.3.10 Oregon

Feldslite Corp of America recently began production from the Coos Bay, Oregon area of a feldspathic sand containing about 50 per cent feldspar. The material is marketed in the Northwestern U.S. and Western Canadian markets for fibre glass. Output is about 10,000 tonnes feldspar content.

3.2.4 United States - Potential Supplies

The pegmatite province of the Eastern United States extends along the Appalachians more or less continuously from Alabama to Maine. Former producing districts with abundant reserves remaining could be brought into production should markets warrant. The Paris-Rumford and Topsham districts in Sourthern Maine and the adjacent Grafton and Keen districts in New Hampshire have large zoned pegmatite resources. The contiguous belt through Massachusetts and Connecticut containing the current producer in the Middletown district, also contains good quality pegmatite reserves in abundance. The extension of the prolific feldspar districts in the Carolinas through the North Georgia and Thomaston-Barnesville districts in Georgia and into East-central Alabama could support production on a North Carolina scale if market conditions were conducive to it. Northward into Virginia, the belt contains numerous pegmatites, the most important of which are in the Amelia district.

A mid-continent belt extending from the Black Hills of South Dakota through the Haystack district of Wyoming and into the Front Range belt of Colorado has very large reserves. Many of these pegmatites contain other minerals such as lithium ores, beryl, niobium and tantalum. The pegmatites of Eastern Manitoba would appear, at least geographically and mineralogically, to be the northward extension of this pegmatite province.

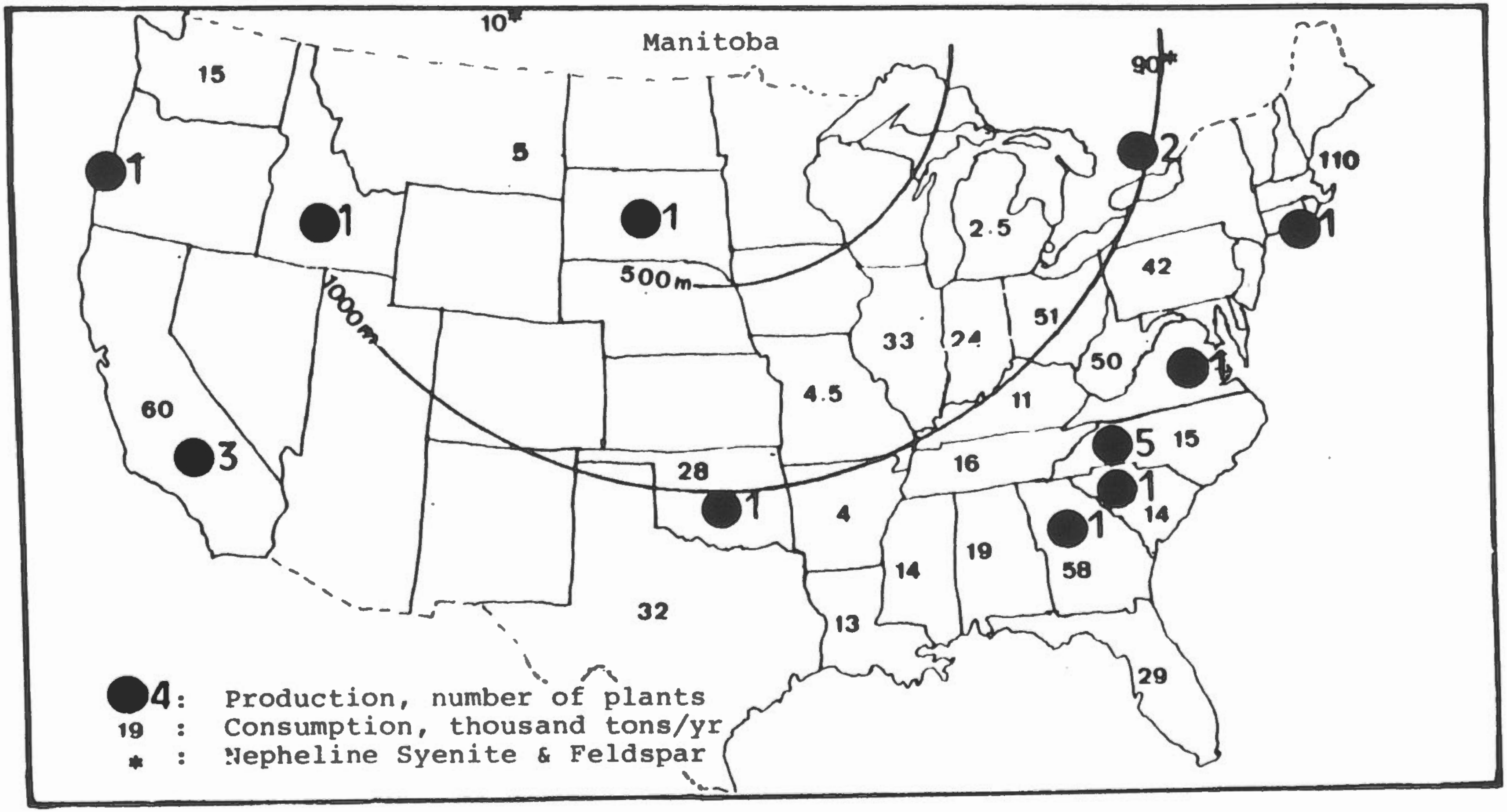

Figure 1: North American Feldspar Production and Consumption Map (1985)

Figures for the U.S.A. are feldspar consumption only: 400,000 tonnes of Canadian Nepheline Syenite is also consumed in the northern states. Consumption estimated from shipment destination data, U.S. Bureau of Mines, Minerals Yearbook 1983.

In the western states, the Avon district of Idaho is a minor resource. The Cottonwood district in Western Arizona, an important former producer, and the Pala district in California, an active feldspar producer, are the only districts of consequence in the far west. Another type of resource west of the Mississippi River is the natural feldspathic sand deposit. A potential producer in this class that has received attention in recent years lies in Chelan County, Washington. Feldslite Corp of America obtained a production lease in 1981 to mine the sand but to date no production has occurred.

In summary, United States excess plant capacity and vast feldspar resources ensure highly competitive conditions for the foreseeable future. The prerequisites for entry into so tight a market are high quality resources and low cost production.

3.3 Demand - North America

3.3.1 Aggregate Feldspathic Market

United States demand for feldspar (1983) is cited in Mineral Facts and Problems, 1985, to be 701,000 short tons (636,000 tonnes) with a major consumption category breakdown of 58.5% for glassmaking, 38.2% for pottery and related ceramic manufacture and 3.3% for other uses including porcelain enamels, fillers, soap, abrasives etc. This picture is incomplete for our purposes. It ignores the 400,000 tonnes a year of nepheline syenite (80% feldspar and 20% nepheline) imported from Canada and an estimated 100,000 tonnes/year of "aplite" (mainly andesine) produced in Virginia. No breakdown on nepheline syenite consumption is given for the United States but it is estimated that over 75 per cent is used in glass manufacturing. All the Virginia aplite is used in glassmaking. Adjusting U.S. figures to include nepheline syenite and aplite, the approximate breakdown of markets for all feldspathic materials is 770,000 tonnes (68%) for glass products, 320,000 tonnes (28%) for pottery and related ceramics and 40,000 tonnes (4%) for enamels, fillers etc.

This is similar to the Canadian consumption pattern. Canada consumes approximately 100,000 tonnes a year of feldspathic materials, 70 per cent for glass, 26 per cent for pottery and other ceramic products and 4 per cent for porcelain enamel, fillers, abrasives etc. Nepheline syenite makes up 95 per cent of Canadian feldspathic material consumption. About 5,000 tonnes of feldspar is imported annually from the United States, all but 100 tonnes or so by whiteware manufacturers.

Using the U.S. Bureau of Mines forecasts (Mineral Facts and Problems, 1985) and applying growth projection to the total U.S. feldspathic materials demand computed above yields the figures in Table IX.

TABLE IX

U.S. Feldspathic Materials Demand Forecasts
(000's tonnes)

End Use	1983	2000 Low	2000 High	2000 Probable
Glass	370 (770)	390 (810)	460 (950)	390 (810)
Pottery	240 (320)	270 (360)	380 (505)	310 (410)
Other	21 (40)	0 (0)	30 (50)	30 (50)
Total	631 (1130)*	660 (1170)	890 (1505)	730 (1270)

* Figures in parentheses include demand for feldspar plus nepheline syenite and aplite.

The USBM forecast (modified by Agricola Mineralia to include nepheline syenite and aplite) for feldspathic material demand was obtained by regression analysis of time series data with various economic indicators and independent forecast of those indicators. The results were then refined subjectively on the basis of assumed contingencies that may enhance or reduce expected demand. This approach is too aggregated and mechanistic for use in a market feasibility study. Moreover, experience suggests that aggregated economic indices are less a determinant of future raw material demand than technological and political trends. The introductory remarks in the outlook section for feldspar in the 1985 edition of Mineral Facts and Problems dwell on the considerable overestimate of demand made for 1980 in the 1965 edition (actual demand was less than half that projected). It was largely based on economic indicators. Since 1963, a new technological revolution, the energy crisis, the end of the colonial era, the escalation and conclusion of the Vietnam War, and environmentalism are but a few of the events that confounded the clockwork of economic indicators. Table X shows the uneven nature of U.S. feldspar demand over this eventful period.

In the following end-use breakdown, the USBM forecasts are reviewed, the critical developments affecting demand are analyzed, and a new forecast derived.

3.3.2 Glass

The USBM demand projection for feldspathic material requirements for glass in the year 2000 was obtained using the U.S. Federal Reserve Board (FRB) Index of Stone Clay and Glass as an explanatory variable. Factors that might augment the projected requirement include improved technology for lighter weight, higher quality container glass that would compete more favourably in the food and beverage packaging industry against aluminum, plastic and paper products. Also, fibre glass for housing insulation and plastic reinforcement may exceed the FRB Index. This provided the basis for the high forecast of 950,000 tonnes (Table IX). For the low forecast of 810,000 tonnes, continued inroads by competing materials for packaging, increased glass recycling and lower demand for glass fibre were considered. Probability was deemed to weigh strongly in favour of the low forecast.

TABLE X

U.S. Feldspar Demand and Production

1963 - 1983

Year	Demand	Production
1963	599	615
1964	647	658
1965	664	700
1966	704	734
1967	663	689
1968	731	748
1969	793	755
1970	648	726
1971	702	743
1972	681	746
1973	769	792
1974	768	763
1975	660	670
1976	734	740
1977	728	734
1978	725	735
1979	728	740
1980	697	710
1981	651	665
1982	604	615
1983	701	710

Source: 1985 Mineral Facts and Problems, Feldspar preprint USBM.

The most serious setback for feldspar envisioned by many analysts is seen to be competition from plastics, aluminum and paper in the food and beverage packaging market, particularly the first mentioned material. Raw materials for plastic (polyethelene terephthalate or PET) has in recent years been over $US 200/tonne ($US 35-40/bbl oil equivalent) compared to about $50/tonne for glass (processing raw materials to final product are assumed to be about the same). However, a tonne of PET is more than twice the volume of a tonne of glass and containers are made much thinner-walled. With the

OPEC cartel collapsing, oil prices have declined (March 1986) to below $US 15.00 a barrel. Although this low price is unlikely to be long lived, container competition was vigorous even at the high prices of the past few years and the advantage could fuel a quicker than anticipated growth in plastic container usage. Once plants are built and expanded, a reversal to glass containers could not be expected in the short term.

In addition to promotional efforts by the Glass Packaging Institute, a $5 million research fund contributed by seven glass makers from the U.S., Australia, Canada, Japan and West Germany was reported on in the July, 1985 issue of the trade journal, Ceramic Industry. The prime push is for stronger, lighter glass containers. Their forecast for container markets by the year 2000 indicates paper retaining its present 50 per cent share; metals contracting from the present 25 per cent to 10 per cent; plastics increasing from 13 per cent to 30 per cent and glass containers shrinking from 12 per cent to a 10 per cent share. Although the share is smaller, the overall market would be larger.

Even granting this optimistic forecast for glass containers, the effect on feldspar is certain to be much more negative. Weight reduction and increased recycling will reduce feldspar demand for glass containers drastically, probably by as much as half by the end of the century. Moreover, the fact that glass container companies are diversifying into the plastic container business, will tend to undermine the vigour of competition to preserve the place of glass, especially given the bottom lime implications of the economics of plastic containers.

A minimum 10 per cent drop in output of glass containers can be expected by 2000 and with a 50 per cent reduction in feldspar requirements per unit, demand for feldspar (including nepheline syenite and aplite) in this sector will decline from the present 500,000 tonnes (Agricola Mineralia estimate) to about 225,000 tonnes. Feldspar could recoup some of its losses in containers, however, as we shall see under the section on fillers.

Flat glass manufacture uses only a small amount of feldspar (0.2 to 1.5%). Annual production of about 3 million tonnes in the United States consumes an estimated 30,000 tonnes of feldpsar. Research into stronger, lighter weight glass for containers may have application in flat glass but this is not likely to have much affect on feldspar consumption for some years to come. Reduced glass per unit in cars has already had its effect and this has been compensated for to a large degree by double and triple glazing of windows in buildings for energy conservation. Recycling is not important in this sector. Demand growth is predicated on automobile sales and building construction which follow economic growth. Assuming average growth of 3 per cent, consumption of feldspar by 2000 would be about 45,000 tonnes.

The fibre glass sector brings better news for feldspar consumption, which is currently about 150,000 tonnes-a-year (Agricola Mineralia estimate) in the U.S. for this use. Fibre glass for thermal insulation has enjoyed rapid growth in response to the oil price spiral of the past decade. Despite the present decline in oil prices (which are likely to turn around again in a year or two), new building codes and a conservation ethic are likely to maintain growth in demand for fibre glass insulation at least at the rate of economic growth.

Projecting to 2000, feldspar (including nepheline syenite, aplite etc) demand for glassmaking is expected to be little changed from the present level. Fibre glass will have surpassed containers as the principal glass product and its high growth rate should continue into the new century. Glass containers should then stabilize their market share at the new level.

3.3.3 Pottery and Related Products

The USBM applied regression analysis of time series data using the New Construction Activity index as an explanatory variable and arrived at a statistical projection of 505,000 tonnes (adjusted for nepheline syenite and aplite) requirement for this category in 2000. This variable was used because of the tie between new construction and demand for sanitary ware, tile, dinnerware, electrical porcelain and the like. The high forecast assumes substantial growth in new housing. Slower growth in housing plus expansion of the trend towards greater imports of tile and other ceramic products was the basis for the low forecast of 360,000 tonnes feldspar equivalent. An intermediate growth rate in housing construction was judged most probable and the expected feldspathic requirement in 2000 was set at 410,000 tonnes.

The foregoing "surprise free" forecast belies the techological revolution that ceramics are undergoing. Formerly synonymous with brick, pottery and tile, ceramics now find application in high precision engine parts for aerospace, automotive and other uses. Indeed an engine made entirely of ceramics has been built in Japan. Although these materials, so-called "fine ceramics", at present are fairly exotic - silicon carbide, silicon nitride, zirconia, boron nitride, aluminum nitride etc., the buzz of activity in ceramic research called "ceramic fever" by the Yano Research Institute of Japan is likely to spill over into all segments of the ceramics industry. MITI, the Japanese government agency, forecasts a market for fine ceramics of $US 25 billion by 2000. Currently this market is $2.65 billion in Japan and up to $650 million in the United States.

Regarding traditional ceramics, earthenware, chinaware and sanitaryware (in new housing and renovation), markets increase with increasing disposable income. A strengthening North American economy, now more likely in the wake of the oil price slide, should contribute to increased demand for these products. Greater demand for electrical insulators (increased power demand) would also result, although, traditionally, this lags housing demand by one year.

Modern North American housing is using more and more ceramic floor, wall and decorative tile than formerly. This young market, a well established tradition in Europe, is likely to enjoy a good growth rate over the next decade or so. In both the ceramic tableware and glazed tile trade, however, imports have grown rapidly, benefitting from the strong U.S. dollar. Over half U.S. consumption is now imported. Despite this, U.S. shipments of these products have, except for the recent recessionary period, enjoyed good growth.

Although no definitive assessment can be made of feldspar's place in the ceramic revolution or how future import trends will go for the other ceramic sectors, most of the pottery and related products specify feldspar and K-feldspar in particular where economics permit. The USBM estimate to 2000 (adjusted to include nepheline syenite and aplite) for this group (410,000 tonnes) seems reasonable.

3.3.4 Other Products

Other uses for feldspar are: in porcelain enamels; as fillers in rubber, paints and plastics; in soaps, scouring powders and welding rod coatings. Analysis of this mix by the USBM, employed U.S. population growth as an explanatory variable, a variable that has been trending downward for the past 15 to 20 years. However, growth as a filler and potential for new uses was projected to build a requirement by 2000 of 50,000 tonnes a year.

Fillers are used to extend and modify the properties of plastics, paint, rubber and other materials. Acceptable feldspathic fillers must be low in iron, be very fine-ground, have a high brightness (reflectance) and low oil absorption. At present, nepheline syenite dominates the market for feldspathic fillers in North America. Low iron feldspars could meet nepheline syenite on equal terms in this market. In fact, AB Forshammars in Sweden recently began production of super fine feldspars (0.2 to 0.3 microns) for use in foam rubber, plastics and paints, expecially outdoor and anti-corrosion paints.

Fillers in the plastics industry are a high growth sector. Since feldspar's refractive index is close to that of most plastic resins, it tends to be transparent when used as a filler. The economics of using mineral fillers (as much as 40% loading), is favourable in terms of improved heat resistance, durability, compressive strength and reduced unit requirement for the higher cost plastic resin. Clearly, lost markets in glass for containers may be offset by demand for feldspar as a filler in plastic containers. This comparatively new use should have a growth rate bearing a relationship with the high growth expected for plastics. Accordingly, it is likely that feldspar demand (including other feldspathics) could easily be triple or more the USBM estimate for this category.

Overall U.S. feldspathic demand is expected to reach 1.33 million tonnes by 2000, for an annual growth rate of just about 1 per cent. Much of the growth will, however, favour feldspar and K-feldspar in particular, yielding a 2 per cent annual growth for this mineral. Canadian consumption is about 10 per cent that of the United States. Given the favourable dollar exchange rate and the opportunity it affords for replacing imports of ceramics and glass, Canadian feldspathic demand should equal or exceed U.S. rates over the balance of the century.

3.4 Nepheline Syenite/Feldspar Competitive Factors

Nepheline syenite as a substitute for feldspar in glass, results in a lower melting temperature of the batch, which saves on energy, extends the life of furnace refractories and produces a more fluid melt. The most important economic advantage of nepheline syenite over feldspar, however, is that a tonne of nepheline syenite contains 39* units of combined alumina and the alkalis (Al_2O_3 = 23.5%; $Na_2O + K_2O$ = 15.5%) to feldspar's 31 units. This factor results in cheaper mining, processing and freight costs per unit of nepheline syenite.

Moreover, nepheline syenite is produced by dry milling, whereas feldspar in the United States is almost all flotation product

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* A unit or ton (tonne) unit is equal to one per cent of a ton (tonne), i.e. 20 lbs for a short ton and 10 kg for a metric tonne. The number of units of a substance in a product is then, equal to the weight per cent determined by chemical analysis. This is standard usage in expressing the amount of the desired substances contained in ores and concentrates.

requiring extra milling and drying costs and associated higher capital costs. Although nepheline syenite's greater number of alkali-alumina units per tonne is also an advantage over Manitoba feldspar, byproduct advantages of the latter will ensure penetration of the feldspar "survival" market which persists within nepheline syenite's reach because of specific requirements for feldspar, in particular K-feldspar.

K-feldspar commands the highest price of all feldspathic materials precisely because of the special requirement for it in such products as high voltage electrical insulators. This higher price was certainly one factor, along with those already discussed, that facilitated nepheline syenite's rapid penetration of markets like the glass industry, which was formerly served by feldspar. There is no question that a lower priced, good quality K-feldspar could regain part of its lost markets. Manitoba feldspar is superior in terms of low iron analyses to its competitors (including nepheline syenite) and this should reinforce its market penetration capability.

The substitution trend of nepheline syenite for feldspar in North America is presently static and will remain so until another nepheline syenite body is opened in a region with access to new markets. Ironically, the nepheline syenite filler grades, which have enjoyed excellent market growth since the early 1970s, are vulnerable to penetration by feldspar-based fillers. This new use for feldspar has been developed in Sweden and is certain, with the potential market for plastic fillers, to appear in North America.

Another development in the nepheline syenite industry that may improve the competitiveness of feldspar, is the recent purchase by Indusmin Ltd. of IMC (Canada) Limited's operation at the Blue Mountain deposit. With Indusmin now enjoying a monopoly in the North America nepheline syenite industry, at least a few of their customers, fearing upward pressure on prices and threats to single source supply by strikes, expect to diversify their sources. In summary, feldspar's prospects vis-à-vis competition from nepheline syenite have never looked better.

3.5 Prices and Tariffs

3.5.1 Pricing Practice

In the United States, prices are quoted by grade in dollars per short ton, bulk, carload lots, fob at producer's plant or point of loading. For consumers who are not equipped for bulk handling and storage, or whose requirements are modest, bagged material is an alternative. Bags, 50 lbs or 100 lbs, add $US 9.25/ton and pallets $7.00/ton.

Distributors are "middlemen" usually serving smaller buyers. Commonly they produce ready mix frits and glazes and often, in part as a customer service, purchase feldspar for direct resale. Prices then include freight to the distributor plus a commission, a practice that saves money for the small buyer who can't use carload lot volumes.

Discount pricing arises in very competitive markets where large buyers negotiate prices. The glass industry is an example of this. The glass container industry operates with small profit margins and given the present state of competition with other packaging materials, price negotiation for raw materials is more vigorous than ever. This makes life difficult for the market surveyor. In contrast to most sectors of the ceramic industry, which are price takers, glassmakers have a tradition of refusing to divulge their supplier's prices.

TABLE XI

Representative 1985 Prices*
$US, bulk carload lots/ton fob. plant

1)	Feldspar Corp, G200 K-feldspar (-325 mesh), fob. Georgia	$76.50
2)	Feldspar Corp, NC4 Na-feldspar (-200 mesh), fob. North Carolina	33.70
3)	Feldspar Corp, K200 K-feldspar (-325 mesh), fob. North Carolina	77.00[e]
4)	Indusmin Ltd. A270 Nepheline Syenite (-270 mesh), fob. Ontario	57.00[e]
5)	Indusmin Inc., Minspar Na-Feldspar (-200 mesh), fob. North Carolina	33.70[e]
6)	IMC, Kona F-4 Na-feldspar (-200 mesh), fob. North Carolina	33.70
7)	Pacer Corp, K-feldspar (-200 mesh), fob. Custer, S. Dakota	85.00[e]

e Estimated by Agricola Mineralia from freight and delivered price data.

* Glass grades (20-40 mesh) vary from $20 to $30/ton.

3.5.2 Price History and Forecast

Average prices for U.S. feldspar (Table XII) between 1963 and 1975 doubled in response to strong economic growth. In real terms prices increased over 10 per cent during this period. Despite curtailment of economic prosperity in North America by rapidly rising energy prices during the 1970s, feldspar prices increased at the rate of inflation. At the same time, however, U.S. production fell from a high of 792,000 tons in 1973 to 710,000 tonnes in 1980. The deep recession of 1980-82 saw a sharp drop in both prices and production. Over the past few years, output and prices have recovered modestly and this trend is expected to continue with pre-recession output and prices being reached by 1987. Beyond that time, average prices are expected to increase moderately by virtue of the changing product mix with demand for lower value glass grade output remaining stagnant and higher value ceramic and filler grades increasing in volume. In the long term, a strong competitive environment will constrain any significant growth in real prices for individual grades. With prices comparatively low in real terms and recovery in progress, however, it is an opportune time for entry of a new supplier.

3.5.3 Tariffs

Tariffs are nominal and therefore not a factor in competition for North American markets. Crude feldspar (TSUSA No. 522.31) is admitted duty free into the U.S. from countries like Canada

TABLE XII

Price History of U.S. Feldspar

Year	Average annual price per short ton: Actual prices	Average annual price per short ton: Based on constant 1983 dollars
1963	8.98	27.02
1964	8.19	24.27
1965	8.94	25.93
1966	9.56	26.86
1967	10.28	28.04
1968	11.05	28.87
1969	11.75	29.20
1970	13.27	31.30
1971	13.42	30.14
1972	14.16	30.54
1973	16.20	33.04
1974	14.94	28.00
1975	17.51	30.02
1976*	23.70	38.62
1977	23.42	36.06
1978	24.76	35.50
1979	29.00	38.27
1980	32.70	39.50
1981	31.60	34.92
1982	33.00	34.40
1983	31.70	31.70
1985[e]	35.00	33.00

[e] Estimated by Agricola Mineralia
* Prior to 1976, prices are for crude ore.

Source: Mineral Facts and Problems, 1985 edition

that are accorded Most Favoured Nation (MFN) status. Non MFN rates are $0.50 per long ton. Ground feldspar (TSUSA No. 522.41) is subject to a declining MFN tariff which, as of January 1, 1984 was fixed at 3.1% ad valorem. This will be reduced to 2.8% ad valorem by

January 1, 1987. The non MFN rate for ground feldspar is 30% ad valorem. There is no tariff on nepheline syenite into the U.S.

3.6 Freight

With low value materials like feldspar, freight tends to be the most important factor in defining the radius of the market. Where a specific composition (e.g. K-feldspar for electrical insulators) is required, however, the product commands a higher price and can bear higher freight. Manitoba feldspar can therefore compete in central New York State for the latter use but is essentially closed out of the Eastern Region for container and fibre glass. For intermediate value ceramic use, Manitoba feldspar can reach central Ohio. Because of limited supplier competition in Western Canada, higher freight charges can be borne but the market then offers an opportunity for new suppliers in the region. Table XIII gives quoted and estimated freight rates to various destinations from Manitoba, North Carolina, Georgia and Ontario.

These rates are for 70 to 90 ton hopper cars. Rates to the United States from Manitoba are given in U.S. dollars and converted to Canadian using a 23 per cent "surcharge". This means that U.S.

TABLE XIII

Selected Freight Rates
$Cdn/ton, bulk carload lots

Destination	Manitoba	Georgia	N. Carolina	Ont. (neph. sy.)
Chicago, IL	60.00[e]	69.00[e]	58.00	55.00[e]
Indianapolis, IN	65.93	62.00[e]	52.00[e]	52.00[e]
Cleveland, OH	72.08	67.40	57.00	48.50
Columbus, OH	70.85	52.00[e]	40.00[e]	49.00[e]
Rochester, NY	79.95	75.00	69.00[e]	-
Cincinatti, OH	68.00[e]	45.00[e]	33.00[e]	52.00[e]
Madison, WI	55.00[e]	-	-	60.00[e]
Denver, CO	83.64	-	-	-
Vancouver, B.C.	69.00	-	-	90.00[e]
Redcliff, Alta.	48.20	-	-	81.90
Edmondon, Alta	-	-	-	86.40

[e] Agricola Mineralia estimates based on delivered price information and interpolation.

dollars are converted at the very favourable rate of 1 to 1.23 on condition the freight is prepaid. The surcharge varies from time to time. Sixty ton boxcar loads in bags are 28 to 30 per cent higher rates than for bulk hopper cars.

Truck load lots in bags, bulk boxes, or bulk pressure trucks to U.S. destinations are more expensive than rail but can be reasonably competitive on intermediate distances (500 to 1000 miles) if they have a backhaul. Rates vary from $Cdn 0.07 to 0.10/ton-mile, compared to about $0.07 for rail to Indianapolis. Long haul rates by rail (e.g. Manitoba to Rochester, New York) are near $0.04/ton-mile. Choice of a carrier depends mainly on the volume of a customer's requirements, their offloading and storage facilities and their distance from a supplier. It should be noted that the Manitoba-to-market rates are published or quoted single car rates and that volume discounts can be negotiated.

An alternative to straight rail or truck is rail to the Lakehead and shipping on the Great Lakes. Given the high volume of the market just south of the Lakes and especially in Ohio, this mode deserves a thorough evaluation during market development.

CHAPTER IV

THE MARKET SURVEY AND ANALYSIS

4.1 Survey Methodology

A threefold approach to gathering market intelligence was used. Using the Directory of Feldspathic Mineral Consumers, Suppliers/Distributors and Research Organizations compiled for this report, a list of consumers, all those known to exist within the reachable U.S. market area shown in Figure 1, was prepared. Twenty firms representing a cross-section of the ceramics and glass industry south of the Great Lakes were selected for personal visits and the remainder (169) were mailed a letter and questionnaire (see Appendix II). All significant Canadian consumers were interviewed by telephone and one was visited in Eastern Ontario.

Concentration of effort on markets south of the Great Lakes was done for several reasons. The size and diversity of the consuming industry in this region and its location in the most active meeting place of virtually all competitive feldspathic materials made the area the best source of intelligence for a study of this kind. Ohio, for example, consumes as much feldspathic material as all of Canada and almost every consuming industry can be found there.

A second reason was that the contractor is already fairly well informed on the Canadian industry and has visited several plants and research organizations during previous work. One whiteware firm was visited in Ontario because, of the total tonnes of feldspar imported into Canada, all but a few hundred tonnes is consumed by the whiteware manufacturers and this industry is concentrated in Eastern Canada. Outside of this industry, nepheline syenite holds sway as the feldspathic ingredient of the Canadian glass and ceramic sectors.

The dispersed nature of the industry geographically, made it practical from both cost and time viewpoints to survey the market by car. Also, since samples of a kilogram or so of one or more feldspar products (glass grade, ceramic grade etc.) were provided to each company visited, use of a car was most convenient.

4.2 Estimated Initial Sales Volume

Figure 1, page 32, shows the distribution and tonnage of feldspar markets in the United States, exclusive of nepheline syenite tonnages. Adding nepheline syenite to this market would roughly double the figures in states north of the Ohio River plus in Pennsylvania and the northeastern seaboard. However, since nepheline syenite has replaced markets in competition with feldspar in these areas, the feldspar figures represent the "survival" market which is open to competition from a Manitoba supplier. Moreover, most of the penetration by nepheline syenite has been into lower value glass grade markets. Some recovery of nepheline syenite markets by feldspar is possible and this will be discussed later.

Given equal quality, costs, dollar exchange rate and therefore fob. plant prices, the geographic market east of the Mississippi River (called herein the Eastern Region) for Manitoba would be within a radius of 750 miles, roughly reaching Chicago, which is half way to the Carolina's and Georgia's feldspar producers. Because Manitoba production would be byproduct in nature and dry processed to the degree possible*, production costs will be considerably lower than for the flotation product of the U.S. Moreover, the low iron content makes Manitoba feldspar a superior product. The biggest advantage of all is the exchange rate. One U.S. dollar is around 40 per cent greater in value which gives a netback premium to a Canadian producer selling in the United States. The stronger U.S. dollar has been a market advantage for about ten years and this situation is likely to continue over the next ten years.

Notwithstanding these advantages, a price discount of about 10 per cent will be necessary to induce buyers to switch from a product they are already happy with, to a product they will have to evaluate. Nevertheless, the advantages in balance should extend the

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* (flotation of a coarse product "28 mesh" may be necessary, followed by drying and dry grinding for ceramic products)

market range an additional 250 miles or so bringing into the reachable market the states between the Great Lakes and the Ohio river and the western parts of Pennsylvania and New York.

A rule of thumb for a competitive product is an initial penetration of 10 per cent, the share a consumer is generally willing to grant at the outset. Because of the recent deep recession following several years of generally poor markets, however, competitive price has taken precedence over security of supply and, in many cases, over raw material specifications. Demand for alternate feldspathic products by most end use manufacturers has changed from highly rigid in terms of price to highly elastic. Where most ceramic manufacturers formerly tended to be indifferent to offers at modest discounts, today the philosophy is "get the cheapest and make it work". This quotation is from a dental ceramic manufacturer (Austenal Dental, Inc.) whose industry was once the most indifferent of all to raw material prices. Research and development, as already learned by glassmakers, has demonstrated to many sectors of the ceramics industry that the "make-it-work" directive is feasible.

In short, many consumers stated that they are willing to shift to a new supplier entirely at a price reduction of 10 to 15 per cent especially if the material is K-feldspar. Assuming a 10 per cent penetration, therefore, gives a conservatively estimated market volume available to a Manitoba producer in the Eastern Region of 14,300 short tons. Larger percentages of the remaining markets are to be expected because of the greater geographical advantage. All together the initial market volume which could be easily captured by a Manitoba operation is expected to be 27,000 tones-a-year which is greater than projected capacity. The market breakdown is presented in Table XIV.

TABLE XIV

Estimated Market Volumes
(tons)

Market Areas	Total Market	Manitoba's Share
Illinois	33,000	3,300
Indiana	24,000	2,400
Ohio	51,000	5,100
Michigan	2,500	500
New York	20,000	2,000
Pennsylvania	42,000	1,000
North Central & Northwestern (US)	15,000	5,000
Eastern Canada	4,000	2,500***
Western Canada	10,000*	5,000
International**	1,000**	200
	202,500	27,000

* Predominantly nepheline syenite
** Dentalspar
*** The high percentage share of Eastern Canada's market crises because there are no feldspar producers in this region

To illustrate the conservative nature of the estimated 27,000 ton market volume, it is worth noting that the K-feldspar requirements (G200, 325 mesh) of just four electrical insulator companies contacted are over 10,000 tons-a-year. Manitoba could gain the upper hand in this market. Since projected output is 75 tons/day, annual production is to be about 22,500 tons (300 days) as a byproduct of spodumene production. There should be no problem, then, in marketing this total volume given a thorough marketing effort.

4.3 Market Profile

4.3.1. The Glass Industry

As discussed under Pricing Practice, it is axiomatic that the glass industry does not provide much information especially on raw material prices paid. Where within range of Canadian nepheline syenite production, or Virginia aplite, the container glass, fibre glass, flat glass and glass tableware manufacturers will obtain all or nearly all of their requirements from these sources. This is simply because of the price. The whole range of feldspathic materials chemistry can be used in these products, the only rigid requirements being for iron and other colourant levels and composition consistency one load to the next. The material is the coarsest grain size, in the range of -20 mesh + 150 mesh, and commands the lowest price, an average of about $US 25.00/ton fob. plant. Glass grade nepheline syenite is below $Cdn 30.00/ton fob. plant.

The glass industry is the largest consuming sector for feldspathic materials. Container glass, fibre glass and flat glass manufacturers are controlled by a relatively few giant corporations. Two of these, Owens-Illinois Inc. and Owens-Corning Fiberglas Corp. of Toledo, Ohio were visited. Owens-Illinois, as expected, did not provide much information on their container business except to confirm that they use mainly nepheline syenite. They are also specialty glass producers with plants at Columbus, Ohio and Pittston, Pennsylvania that use substantial tonnages of K-feldspar from a U.S. producer.

Owens-Corning Fiberglas was even less forthcoming. It is known that for their insulation products, even lower quality feldspathics than for containers can be used. Formulations of high strength reinforcement fibre reported to yield tensile strengths up to 650,000 psi are, at present, U.S. military classified information. Whether these, or possible new formulations, will use K-feldspar is not known.

Anchor Hocking Corporation, near Columbus, Ohio, is a large U.S. tableware company currently buying feldspar and aplite in bulk, carload lots. They are an example of a company that would shift 100 per cent to a new feldspar source at a delivered price discount of 10 per cent from current prices. At present they obtain International Mineral and Chemical Corp's Na-feldspar from North Carolina and Feldspar Corp's aplite from West Virginia at prices we estimate to average $65/ton delivered. This price for glass grade cannot be beaten by Manitoba.

In summary, the Eastern Region market is the area most penetrated by nepheline syenite and glassmakers are the major consumers of it. From Ohio eastward, Manitoba cannot compete at all with glass grade nepheline syenite, nor with similar grades of feldspar and aplite from the Carolinas and Virginia. Moreover, the low value of glass grade and high freight charges in general make the kind of aggressive price competition needed in the western part of the Eastern Region unattractive to a Manitoba supplier which should have no trouble marketing an adequate volume of higher value ceramic grades. Television picture tubes and other specialty glassmakers who specify K-feldspar, of course, are exceptions.

The glass industry in Eastern Canada uses only nepheline syenite because of the freight advantage and low value of the material. In Western Canada, the natural market for a Manitoba producer, two factors of recent origin have reduced market potential. First, Domglas Inc.'s Vancouver plant and Consumers Glass Co. Ltd.'s Lavington, British Columbia plant have recently closed. Second, a feldspathic sand producer, recently reopened in Emmett, Idaho and a new facility at Coos Bay, Oregon are shipping into Western-North America. Approximately 3,000 tons/year of sand from Oregon (1500 tons feldspar) is used in fibre glass manufacture in Western Canada. Northwestern Glass in Washington State obtains 25,000 - 30,000 tons/year of sand from Idaho. Domglas Inc. at Redcliff, Manville Canada Inc. at Innisfail, and Fiberglas Canada Ltd. at Edmonton, all in Alberta, together use about 6500 tons of nepheline syenite a year.

Delivered prices from Coos Bay, Oregon to Southern British Columbia are about $Cdn 60/ton for a feldspathic sand which is only half feldspar. If a suitable silica sand source were locally available for a delivered price of $15 to $20 a ton, then the value of the silica sand portion of a ton of Coos Bay material would be only $8-10 and the half ton of feldspar would be the balance of $50 to $52 or about $100/ton. Such a situation would require an fob. price in Manitoba for glass grade feldspar of $30/ton to be competitive.

Regarding competition with nepheline syenite, the delivered price for glass grade nepheline syenite from Havelock, Ontario to Alberta destinations averages about $Cdn 110/ton. Because of the higher alumina plus alkalis analysis of nepheline syenite of 39.1 units compared to Manitoba feldspar's 32 units[1] the delivered cost per unit must be equalized. For nepheline syenite, the delivered cost per unit is then:

$$\frac{110}{39.1} = \$2.81.$$

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1. Table III gives 29.99 units for the latter but it is recommended in this report that the free silica content be reduced to yield a 32 unit product.

The delivered price for Manitoba feldspar must then be 32 x \$2.81 = \$90/ton to meet the competition. Because silica is comparatively expensive out West (\$60/ton delivered), the units of contained silica, normally ignored, would improve the latter figure by as much as 10 per cent. Nevertheless, energy and refractory lining economies realized using nepheline syenite, and the cost and risk associated with switching materials indicate that an initial delivered price of about \$80/ton would be required to make the switch worthwhile. This translates into an fob. Manitoba price of about \$Cdn 30/ton for glass grade feldspar. A market penetration of about 5,000 tons could be realized in Western Canada. An added benefit would be improvement of the economic viability of this region's glass industry, which has been declining over several years. The loss of nepheline syenite markets would represent a mere one per cent.

4.3.2 The Ceramic Industry

The ceramic industry, like the glass industry, attempts to adjust to changes in the feldspathic supply matrix to reduce raw material costs. Indeed, given the comparatively higher feldspathics content of ceramic products, this factor would seem to be of greater importance in the ceramic industry (Table XV). As a whole, however, this industry is constrained to a greater degree by material specifications, and for those end use sectors that have the flexibility to adjust there is usually a price to be paid in terms of quality. For some, there is no substitute for K-feldspar. As a general rule, it can be said that most major ceramic product manufacturers at least prefer K-feldspar from a technical standpoint if they do not actually require it.

Ceramic feldspathic materials are avaible in two main particle sizes: -200 mesh and -325 mesh which sell in the $US 33 to 85 range, the lower prices being for Na-feldspar, the higher for K-feldspar. Nepheline syenite competes as a Na-feldspar type product. Its 270 mesh sells for about $US 58.00/ton fob. Ontario in bulk. Bulk railcar freight rates, to central Ohio from Ontario are around $US 35 to 40/ton.

TABLE XV

Composition of Ceramic Bodies by Weight Per Cent

Product	Ball Clay	China Clay	Flux*	Quartz	Other
Wall Tile	30	20		50	10[1]
Earthenware	25	25	15	35	-
Vitreous China, Sanitaryware	20-30	20-30	15-25	30-40	0.3[2]
Porcelain Insulator	10	60	15	15	-
Bone China	-	25	25	-	50[3]
Engobe	5-15	30-50	20-35	15-30	-
Electrical Porcelain			20-50		
Vitreous enamel frits			10-30		
Glazes			30		

1. Limestone and other minerals. 2. Talc 3. Bone ash
* Mainly feldspathic material. Adapted from The Economics of Feldspar, Roskill, 1984

The ceramic industry is made up of a large number of mainly small to medium sized, independent companies. A wide range of products is produced. This organizational structure minimizes the ceramic industry's power to affect prices for their raw materials and, therefore, ceramic grade feldspar sales return a higher rate of profit to producers. Such a situation opens a niche in the market for intermediate distributors who buy large tonnages in bulk and distribute it either as received, or in the form of custom mixed materials to mainly small buyers. The distributor normally acquires a variety of ceramic raw materials for resale to the industry. Most of the larger companies do purchase their own but they, too, are basically price takers.

4.3.2.1 Electrical Insulators

High tension electrical insulators and electrical porcelain insulators are composed of 15 to 50 per cent K-feldspar by weight and, as such, are the principal end users of high quality K-feldspar. Victor Insulators, Inc. of Victor, New York, Lapp Insulator Co. (Lapp Division of Interpace Corporation) of LeRoy, New York, Industrial Ceramics Inc. of Lima, New York and Ohio Brass Company of Barberton, Ohio together obtain 10,000 to 12,000 tons of K-feldspar from North Carolina (K-200), Georgia (G200) and South Dakota. Most of the material is 325 mesh and this is preferred but some 200 mesh is being used. Interpretation of Corning Engineering findings indicate Rb-feldspar should prove to be superior to the materials now being used.

This industry has been slow over the past five years but would appear to be recovering. About 25 electrical insulator and electrical porcelain companies are operating in the market reachable by Manitoba, including Canadian producers, Independent Procelain Co. Ltd. of Medicine Hat, Alberta and Smith and Stone (1983) Inc. of Georgetown, Ontario. Annual consumption is 20,000 tons of K-feldspar. At an fob. price, bulk rail cars, Manitoba point of loading of about $Cdn 75/ton for 325 mesh a 10-15 per cent delivered price discount would result. Some 7,000 - 8,000 tons of this market would likely be obtainable initially.

4.3.2.2 Sanitaryware

Vitreous china and enamelled steel sanitaryware are manufactured by six companies in eleven plants in the Eastern Region (see Directory). Annual feldspar consumption is roughly 4,500 tons of 200 mesh material. Formerly, K-feldspar was specified, especially for the glaze, but the lower price of Na-feldspar and nepheline syenite resulted in a considerable changeover. The ceramic body itself uses 15-25 per cent feldspar but, since 30-40 per cent silica is also added, a feldspar-quartz mix can be used where convenient. The Kokomo Sanitary Pottery Corp, an affiliate of Gerber Plumbing Fixtures Corp. in Kokomo, Indiana uses a Feldspar Corp product called Silispar which is a Na-feldspar quartz mixture running 76 per cent SiO_2. The Na-feldspar NC4 from the supplier is used as a glaze. The delivered price for the NC4 to Kokomo, Indiana is approximately $US 75/ton, putting Manitoba feldspar out of the running in Indiana and eastward at an fob. plant price over $Cdn 38/ton.

A Universal-Rundle Corp plant at Milwaukee, Wisconsin, and Kohler Co. at Kohler, Wisconsin using about 500 tons a year total, should switch at an fob. price of $Cdn 55/ton for 200 mesh.

Although many of the sanitaryware/whiteware plants in the U.S. and Canada have switched to nepheline syenite, Canadian plants still use up to 4,000 tons of feldspar a year, most of which is consumed in Ontario and Quebec. This material is shipped from the Carolinas and Georgia via a distributor (probably Ferro Industrial Products, Limited) in Oakville, Ontario and delivered prices to Ontario and Quebec range from about $Cdn 225 to 300/ton bagged. A Manitoba plant could ultimately take over much of this market. About 2,000 tons a year is an achievable initial penetration at fob. prices of $Cdn 55/ton and 75/ton for 200 and 325 mesh.

4.3.2.3 Porcelain Enamel

Feldspar makes up 10 to 30 per cent of the vitreous enamel coating applied to metal sheet, cast iron and other products used in household appliances, industrial equipment, signs and the like. Estimating the volume of the feldspar market represented by porcelain enamelers is made difficult by the fact that most of the 20 or so companies in the reachable market obtain frits compounded by distributor/suppliers. Ferro Corp of Cleveland, Ohio and Oakville, Ontario, Ceramic Color and Chemical Mfg. Co. of New Brighton, Pennsylvania, Chi Vit Corp of Urbana, Ohio, Eagle Picher Industries, Inc. of Cincinatti, Ohio and Hommel, O. Co. of Pittsburg, Pennsylvania, also supply many of the pottery and dinnerwar industries with glazes and other products, as well as handling pure feldspar for resale. Two of the larger companies, Ferro Corp. and Chi Vit Corporation (an Eagle Picher subsidiary) together buy about 10,000 tons a year of U.S. feldspar, 1,500 tons of which is K-feldspar for distribution in the Eastern Region. The U.S. Bureau of Mines estimates total U.S. consumption in 1983 for procelain enameling and minor uses at 23,000 tons. The Eastern Region porcelain enamel market certainly accounts for at least 10,000 tons. At $Cdn 55 and 75/ton fob. Manitoba for 200 mesh and 325 mesh, an adequate discount is provided to secure at least 2,000 tons of the market. Delivered cost for 325 mesh K-feldspar from Georgia to Cleveland, Ohio, for example, is $US 125.30/ton ($Cdn 172.90) and freight from Manitoba to Cleveland is about $Cdn 72.00/ton.

4.3.2.4 Artware, Dinnerware, Stoneware

Twenty-five pottery and dinnerware companies are located in the market reachable by Manitoba. This represents over half the North American market. On the basis of U.S. production[1] of approximately

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1. Summary of Trade and Tariff Information, Ceramic Table and Kitchen Articles, USITC Publ. 841, Feb. 1984. Production was given only in value, but imports were given in 1000 dozens and these represent just over 50 per cent of U.S. consumption.

45 million dozen "ceramic table and kitchen articles" (does not include mugs, crocks and miscellaneous vessels) with an average weight of 0.3 kg and containing 20 per cent feldspar (or nepheline syenite) this sector consumes about 36,000 tonnes feldspar equivalent. Adding the other pottery items raises this tonnage to around 50,000 tonnes annually.

The Eastern Region's consumption of feldspathics (feldspar and nepheline syenite) for this sector is 25,000 to 30,000 tons a year. Many manufacturers obtain their glazes and feldspar for ceramic bodies from distributors like Ferro Corp and Hommel, O. Co. This does not appear to be based on size, however, since companies both large and small also buy directly from producers.

A few large companies like Pfaltzgraff Co. of York, Pennsylvania, Anchor Hocking Corp (Shenango China) of New Castle, Pennsylvania, Hall China Co. of East Liverpool, Ohio and Mayer China of Beaver Falls, Pennsylvania consume over half the feldspathics materials used in this sector.

Most dinnerware-stoneware companies are now using Na-feldspar simply because it is cheapest. Pfaltzgraff Co. expressed an interest in high K-feldspar for glaze development. They are aware that K-feldspar is expensive, and a discount would be necessary. Manitoba feldspar would barely be competitive for this company unless the Rb content was of special interest.

The majority of the dinnerware-pottery companies is in Ohio, two are in Indiana, three in Illinois and one in Ontario (Edgewood Potteries of Toronto).[1] These consume about 15,000 tons of feldspathics annually and a Manitoba facility should have little trouble in capturing 3,000 tons of this with an fob. Manitoba price of $Cdn 55/ton for 200 mesh material. Some of the main customers would be distributor companies.

4.3.2.5 Ceramic Tiles

Glazed and unglazed wall and floor tiles and decorative tiles are manufactured by eight companies in this market reachable from Manitoba. Consumption volume of feldspathics in this end use is not published, although U.S. Department of Commerce figures for floor and wall tiles for the 12 months ending August, 1984 total 30.5 million square metres. Assuming half these are glazed, the feldspar requirement is about 10,000 tons. Over half this tonnage would be consumed in the Eastern Region, much of it in Ohio. Manitoba 200 mesh feldspar at $Cdn 55/ton fob. with freight charges of $Cdn 70.85/ton (CP rail published quote, see Table XIII) could be delivered to central Ohio for $126/ton. This compares with nepheline syenite delivered for $128.90 ($US 93.40/ton to Mansfield, Ohio); NC4 Na-feldspar $102.95 ($U.S. 74.60 to Mansfield). Negotiation of a better

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1. The well known Blue Mountain Pottery Limited of Collingwood, Ontario went into receivership early in 1986.

freight rate on tonnage would make Manitoba feldspar competitive in central Ohio. Cambridge Tile Mfg. of Cincinatti is interested in K-feldspar for glaze and would like to replace nepheline syenite. Manitoba feldspar could be delivered to Cincinatti for about $Cdn 120/ton compared with $134 for nepheline syenite. Canadian K-feldspar beats Georgia K-feldspar to Southern Ohio by about $Cdn 10/ton. A Manitoba supplier could expect to capture 1,500 tons/year initially in this market.

4.3.3 Miscellaneous Markets

The major glass and ceramic end use categories surveyed and covered in the previous two sections are conservatively estimated to provide markets for about 17,000 tons/year of Manitoba feldspar. Since the total market for feldspar in the reachable market, not counting nepheline syenite, is over 200,000 tons a year (Table XIV), there is little doubt that the additional 5,000 - 6,000 ton output from Manitoba can be easily sold. Owens-Illinois Inc. alone uses more than this amount in making television picture tubes and other technical glass products that require high K-feldspar. Corning Glass Works, RCA Corp, and General Electric Company are other large specialty glass producers. Art pottery, hobbyist supplies, spark plugs, refractory products and other ceramic sectors represent additional potential customers for Manitoba feldspar. Fillers, as yet an undeveloped market for feldspar, have considerable potential as a competitor to calcium carbonate, talc, nepheline syenite, and other filler minerals in paints/plastics, rubber, adhesives, and caulking compounds.

Changes favoring lower costs have begun to affect raw material requirements for the dental porcelain industry. Dentalspar, a high quality K-feldspar, usually requiring handpicking, has commanded prices up to $1000 a ton. The recent recession, which resulted in a big drop in the cosmetic dentistry business, has led to research into use of lower price feldspar. Austenal Dental, Inc. of Chicago is an example of a company that has had some success in "making it work". The procedure involves buying a tonnage of standard good quality flotation feldspar sufficient to last 10-15 years at competitive prices and formulating with additives.

The history of the dental industry has been one of declining feldspar use. Earlier in this century, the entire denture was made of porcelain. In the middle years, only the teeth were made of porcelain and these were set into plastic arches. Today, although porcelain teeth are preferred, lower cost, acrylic plastic teeth have made substantial inroads into the market. One promising development that could increase dental procelain demand considerably would be popularization of a new technique for reinforcing natural teeth with porcelain slivers, or slips, cemented directly to the tooth.

Austenal Dental Inc. personnel like the chemistry of the Rb-feldspar. Subject to testing, this feldspar could capture a fair proportion of the 100 to 150 tons-a-year North American market if shifts to cheaper spar became general throughout the industry. The European and Japanese industries are also likely to be interested.

CHAPTER V

NETBACK AND PROFITABILITY

5.1 Methodology

Netback to the producer is equal to the delivered competitive price minus freight, handling and marketing costs and adjustments for discounts and tariffs. Subtracting production costs and royalties yields operating profit. Estimated and actual market prices based on the market survey are used in conjunction with representative freight rates to arrive at recommended fob. mine prices.

Obtaining capital and operating costs through engineering feasibility evaluation is beyond the scope of this study. For our purposes, indicative operating costs based on information on plants grinding material of similar toughness are used to arrive at a profitability estimate useful for decision-making.

5.2 Fob. Manitoba Plant Prices

Competitive pricing is discussed in the market profile section and further elaboration and fine tuning is not warranted at this stage. A market development phase would use these recommended prices (Table XVI) as a basis for negotiation. They provide a minimum discount of 10 per cent at freight rates given in Table XIII.

TABLE XVI

Recommended Prices Fob. Manitoba

Product	$Cdn/ton, bulk
Glass grade -40 mesh + 150 mesh	$30.00
Ceramic -200 mesh	$55.00
Ceramic -325 mesh	$75.00

With market experience and full acceptance of Manitoba feldspar, price changes could be implemented and the product mix altered. For example, glass grade output could either be reduced in favour of ceramic grades which return a higher profit or, if production increases are feasible, overall output could be increased. The latter might be effected by using existing tailings, although a study of the material would be needed to ascertain its suitability.

5.3 Operating Costs

Costs are assumed to begin for feldspar production at the point where it has been separated as a byproduct. All costs to this point are charged to primary mineral production. Operating costs cover labour, overhead, drying, grinding, screening, fine sizing, maintenance, loading, trucking to rail and loading on board.

Glass grade costs are, of course, considerably lower than those of the ceramic grades since the total tonnage would be screened off after primary grinding. The ceramic grades require additional equipment including ceramic lined and charged mills, higher power consumption and more operating surveillance and maintenance. Higher administration and overhead for the ceramic grades relate to the above and to the greater complexity of the market.

TABLE XVII

Operating Costs-to-Rail Estimates

	Glass gr.	Ceram-200	Ceram-325
PRODUCTION (tons/yr)	5,000	10,000	10,000
Op. labour ($125,000/yr)	1.00	5.00	7.00
Maintenance labour	0.50	1.50	2.00
Admin/overhead	1.00	3.00	3.00
SUPPLIES			
Grinding, classifying	1.50	3.00	4.00
Drying (coarse from sink-float)	2.00	2.00	2.00
Maintenance	.50	2.00	3.00
Power	1.50	3.50	5.00
Load/haul to fob rail	5.00	5.00	5.00
Total $Cdn/ton	13.00	25.00	31.00
Annual operating cost	65,000	250,000	310,000

5.4 Profitability

Profitability here refers to net (before-taxes-and-royalties) operating profit. No attempt is made to deal with capital costs and their reduction. The figures calculated in the following table are indicative only; a detailed engineering study would be required to determine accurate specific costs.

TABLE XVIII

Operating Profit

Product	fob price $Cdn/ton	op. cost $Cdn/ton	Op. Profit $Cdn/ton	Op. Profit Annual
Glass gr.	30	13.00	17.00	85,000
Ceram-200	55	25.00	30.00	300,000
Ceram-325	75	31.00	44.00	440,000
		Total Annual Op. Profit		$825,000

The profit indicated is an estimate for the first full year of operation. In subsequent years, recovery of the discount, and return of market prices to pre-recession levels and market development would increase profit substantially.

CHAPTER VI

ENVIRONMENTAL CONSIDERATIONS

Problems with feldspar are limited to the immediate plant area and the greatest concern would be over dust production from a dry milling circuit. The presence of quartz dust associated with feldspar production is particularly hazardous, prolonged exposure in the work environment often leading to silicosis, a chronic respiratory illness. Adequate protection of mill and handling personnel from dust is therefore essential.

Since environmental affairs associated with the workplace are the responsibility of the province, the federal Department of the Environment issues no regulations per se. They do, however, serve in a consultative capacity through such bodies as the Federal-Provincial Advisory Committee on Air Quality. Manitoba's Environmental Management Division does not issue regulations specifically for feldspar but does have "Objectives and Guidelines" for "dustfall" and "suspended particulate matter". Table XIX gives ambient air criteria for these.

Virtually all environmental agencies, including those of other countries, use "Threshold Limit Values " (TLVs) for chemical substances, physical agents and biological exposure indices adopted

TABLE XIX

Manitoba Objectives and Guidelines

for Dustfall and Particulates

Contaminant	Classification	Units	Period of time of measurement	Max. Tolerable	Max. Acceptable	Max. Desirable	Reference*
Dustfall In Excess of Normal Background Levels	Guideline	milligrams per square centimetre (tons per square mile/ month)	air basin average- 30 days		0.8 (22.8)	0.6 (17.1)	IV
			single point 30 days		1.5 (42.8)	1.1 (31.4)	
Suspended Particle Matter	Objective	micrograms per cubic metre	24 hrs. average	400	120		
			Annual geometric mean		70	60	II

* Reference

IV Environmental Health Laboratory, 1971, Internal Committee, Manitoba Department of Health.

II Fisheries and Environment Canada, 1976, Criteria for National Air Quality Objectives, Federal-Provincial Committee on Air Pollution, pp, Nov. 1976.

by the American Conference of Governmental Industrial Hygienists (ACGIH), a consultative body of international experts organized in

1938. TLVs are specifically for the workplace. The TLVs are recommendations widely used as guidelines by industry, government and labour unions but they do not have the force of law.

For so-called "Nuisance particulates", or dust without serious toxic effects (1% quartz), TLVs of $10 mg/m^3$ of total dust or $5 mg/m^3$ of respirable dust is recommended. For silica (SiO_2) in the form of quartz the TLVs adopted for 1984-85 are as in the following table.

TABLE XX

TLVs for Dusts (ACGIH)

Substance	TLV
SILICA, SiO_2	
Crystalline Quartz [14808-60-7]	TLV for respirable dust in mg/m^3: $\frac{10 mg/m^3 *}{\% \text{ Respirable quartz} + 2}$
	TLV for "total dust", respirable and non-respirable: $\frac{30 mg/m^3}{\% \text{ quartz} + 3}$

* Both concentration and per cent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic Diameter (um) (unit density sphere)	% passing selector
2	90
2.5	75
3.5	50
5.0	25
10	0

Notice of intended changes that may or may not be finally adopted is also listed. For quartz, a 0.1 mg/m^3 of respirable dust is suggested. Such recommendations are trial limits that may be adopted after two years if no evidence comes to light that the limits are inappropriate.

These guidelines apply in-plant and at facilities subsequently handling the material. For transport, ambient air standards apply and covered or enclosed rail cars and trucks are used. This precaution also guards aginst material loss and contamination of high quality product. All guidelines are constantly under review and new guidelines are adopted for substances for which new evidence indicates a need for revision.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

This study has determined the following:

1) Mineralogical, chemical, beneficiation and glass melt tests on a sample of Manitoba Rb-feldspar indicate that high quality feldspar products can be produced from this unique material. The material is unsurpassed in its low iron content and the presence of rubidia as a significant component promises a superior performance as an ingredient in ceramics and specialty glass products requiring K-feldspar.

2) Economic analysis of the North American feldspar consuming sectors assesses overall demand growth as being a slow one per cent per annum, mainly because of competition with plastics in the container industry. The ceramics industry is somewhat better off and demand growth for K-feldspar should be about 2 per cent a year. Notwithstanding these modest growth rates, conditions for entry of a new producer from Manitoba are good. Prices have bottomed out and should increase over the next few years. Favourable exchange rates, low production costs and a premium product support delivered prices to major consuming centres adequate to dispose of projected production at a good profit.

3) The market survey elicited strong interest in Rb-feldspar, most notably from the ceramic sector. Subject to the normal testing required, several buyers indicated a willingness to accept 50 to 100 per cent of their feldspar requirements from the new source, given a better price than they currently pay.

A development stage for progression towards production is recommended. The following are the principal elements of this process:

1) Production of a few tons of material from the heavy media concentrator.

2) Custom milling to ascertain process and plant requirements. The objective should be to produce products by dry milling. Silica should be reduced to produce ceramic products with 32 units of alumina plus alkali oxides. Screening of coarse grind may reduce free quartz in finer products.

3) Evaluation of tailings for processing.

4) A market development and promotion stage during which pilot plant products would be provided to customers for plant trials, prices negotiated and letters of intent to purchase obtained. This stage would include development of a strategic transport/storage terminal/distribution plan to take advantage of tonnage freight economies and provide good customer service.

RESOURCES

A) Books

1) The Economics of Feldspar, 4th ed., 1984, Roskill Information Systems.

2) Feldspar, Nepheline Syenite and Aplite, (Chapter) Minerals Yearbook, 1983, USBM.

3) Feldspar, (Chapter), Mineral Facts and Problems, 1985, USBM.

4) Nepheline Syenite, (Chapter), The Mineral Investor's Handbook, Agricola Mineralia, Publication, 1985.

5) Nepheline Syenite and Feldspar, (Chapter), Canadian Minerals Yearbook, 1983/84.

6) Modern Plastics Encyclopedia, (re: fillers and fibre glass reinforcement), McGraw-Hill, 1981-82.

7) Feldspars (Chapter), Industrial Mineral and Rocks, 5th ed., 1983, AIME publication.

B) Journals

1) High Technology (magazine), various issues, re: new materials, plastics, ceramics, composites.

2) Journal of the American Ceramic Society, 1985 issue, American Ceramic Society Bulletin, various issues.

3) British Ceramic Transactions and Journal, 1985 issues.

4) Interceram, various issues, notably Feb., June and Oct. 1985 re: talc in tile bodies.

5) Ceramic Industry, various issues, notably July and August 1985 re: performance and R and D in glass industry.

6) Industrial Minerals (magazine), various issues.

7) Canadian Ceramics Quarterly, various issues, notably April 1981, August 1981.

C) Other

1) TLVs(R), Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment and Biological Exposure Indices with Intended Changes for 1984-85, American Conference Governmental Industrial Hygienists.

2) Manitoba, The Clean Environment Act, Queens Printer, Manitoba, 1985.

3) Manitoba, Environmental Management; Objectives and Guidelines for Various Air Pollutants - Ambient Air Criteria, July 1985.

D) Personal Contact

1) Federal Department of Energy Mines and Resources, Mr. George Barry, Mr. Michel Boucher, Ms. Helen Webster, Ms. Karen Ginsberg.

2) Manitoba Ministry of Energy and Mines, Dr. David McRitchie, Mr. Archimedes Gamvrelis.

3) U.S. Bureau of Mines, Mr. Michael Potter.

4) U.S. Department of Commerce, Information Service (re: glass and ceramics industries).

APPENDICES

APPENDIX I

A DIRECTORY OF NORTH AMERICAN FELDSPATHIC CONSUMERS, MINERAL ASSOCIATIONS, SUPPLIERS/ DISTRIBUTORS, AND RESEARCH ORGANIZATIONS

Artware, Dinnerware, Stoneware

Anchor Hocking Corp.
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Bennington Potteries Inc.
Box 199, 324 County St.
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Ric Swenson

Blythe Matthey Ltd.
195 Heart Lake Rd. S.
Brampton, Ont. L6W 3N6
(416) 453-4581
D. G. Whittaker

Buffalo China, Inc.
Box 146
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(716) 824-8515
F. L. Rudesill

Coors H.F., China Co.
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Don H. Beard

Corning Glass Works
Houghton Park
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William R. Prindle

Eisenmann Corp.
Temtek-Allied Div.
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13236-76th Ave.
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Fels Refractories, Inc.
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Ferro Corp.
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E. F. Apple

Gorham Div., Textron, Inc.
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San Dimas, CA 91773
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A. L. Hoskison

Hadley Pottery Co., Inc.
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Haeger Industries, Inc.
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Hartstone, Inc.
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HCP Industries
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Lyle Weideman

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L. M. Taylor

Hyalyn, Ltd.
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Warner Bolick

Ilka Ceramics, Inc.
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Indiana Glass Co.
Sub. of Lancaster Colony Corp.
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Harvey P. Cahoon

Kraftile Co.
800 Kraftile Rd.
Fremont, CA 94536
(415) 793-4432
J. F. Kraft

London Tiles, Inc.
Box 31
New London, OH 44851
(419) 929-1551
R. N. Danison

Lone Star Ceramics Co.
Box 810215
Dallas, TX 753810215
(214) 247-3111
Gowan L. Cecil

Maple Leaf Ceramics
Montreal, QUE
(514) 334-2850
Bill Vallea

Metropolitan Industries, Inc.
Box 9240
Canton, OH 44711
(216) 484-4871
Telex: 752929
J. Steven Renkert

Mid-State Tile
A Mannington Co.
Box 1777
Lexington, NC 27292
(704) 249-3931
Telex: 756756
Fred H. McIntyre, Jr.

Monarch Tile Mfg., Inc.
Marshall Div.
Box 1119
Marshall, TX 75670
(214) 935-7928
TWX: 910-760-5707
Bob Stevens

Sikes Corp.
Florida Tile Div.
One Sikes Blvd.
Lakeland, FL 33802
(813) 687-7171
TWX: 810-867-0465
Telex: 807280
Kelley E. Norton

Stark Ceramics, Inc.
Box 8880
Canton, Oh 44771
(216) 488-1211
John H. Stewart, Jr.

Structural Stoneware, Inc.
Box 119
Minerva, OH 44657
(216) 868-6434
Telex: 983464
Daniel C. Whitacre

Sunstone Corp.
Box 763
Cambridge, OH 43725
(614) 432-5625
Philip J. Rich

United States Ceramic Tile Co.
Box 8049
Canton, OH 44710
(216) 866-5531
Telex: 983437
Tyge Kyhn-Hansen

Victor-Marsh
Div. of TCB, Inc.
1227 Hennepin Ave.
Minneapolis, MN 55414
(612) 331-8880
Marshall Sipkins

Von Tury Ceramics
11 Colonial Ct.
Metuchen, NJ 08840
(201) 549-0071
F. Joseph Von Tury

Wenczel Tile Co.
Box 5308
Trenton, NJ 08638
(609) 599-4503
Telex: 843-393
Walter R. Wenczel

Wenczel Tile Co. of Florida, Inc.
Box 19368
Tampa, FL 33686
(813) 839-5301
Robert J. Corless

Whitacre-Greer Fireproofing Co.
E. Libson St.
Waynesburg, OH 44688
(216) 866-9331
J. B. Whitacre, Jr.

Winburn Tile Mfg. Co.
Box 1369
Little Rock, AR 72203
(501) 375-7251
R. E. Moulden

Directory of Feldspathic Mineral Associations

American Ceramic Society, Inc.
65 Ceramic Dr.
Columbus, OH 43214
(614) 268-8645
Richard M. Spriggs (P)

Associated Glass & Pottery Mfgrs.
2800 E. Military Rd.
Zanesville, OH 43701
(614) 452-8329
Wm. Blenko (P)

Brick Institute of America
11490 Commerce Park Dr., No 300
Reston, VA 22091
(703) 620-0010
Alan H. Yorkdale

Ceramic Educational Council
65 Ceramic Dr.
Columbus, OH 43214
(614) 268-8645
William B. Shook (P)

Dry Process Ceramic & Steatite Mfgrs. Assn.
25 N. Broadway
Tarrytown, NY 10591
(914) 332-0040
C. Byrne (S)

Flat Glass Marketing Assn.
3310 Harrison
Topeka, KA 66611
(913) 266-7013
Thomas O'Malley (P)

Glass Packaging Institute
6845 Elm St., Suite 209
McLean, VA 22101
(703) 790-0800
W. W. Sadd

International Ceramic Assn., Inc.
Box 39
Glen Burnie, MD 21061
(301) 987-9482
Loretta DeFilippis (P)

National Ceramic Mfgrs. Assn., Inc.
3008 Millwood Ave., Box 11187
Columbia, SC 29211
(803) 252-5646
Herb Stampfl (P)

National Institute of Ceramic Engineers
65 Ceramic Dr.
Columbus, OH 43214
(614) 268-8645
Norman H. Harris (P)

Refractories Institute
301 Fifth Ave., Suite 1517
Pittsburgh, PA 15222
(412) 281-6787
M. S. Gleeson (P)

Society of Glass Decorators
207 Grant St.
Port Jefferson, NY 11777
(516) 473-0232
A. E. Warsinsky (P)

Tile Council of America, Inc.
Box 326
Princeton, NJ 08542
(609) 921-7050
J. V. Fitzgerald

Directory of Feldspathic Mineral Suppliers & Distributors

Able Supply Co.
Able Refractory Products
Box 912
Houston, TX 77001
(713) 926-9623
TWX: 910-881-1744
Wayne Pratt

Canada Colour & Chemicals Ltd.
80 Scarsdale Rd.
Don Mills, ONT M3B 2R5
(416) 444-2592
G. W. Stephen

Ceramichrome, Inc.
Box 327
Stanford, KY 40484
(606) 365-9193
James M. Miller

Edgewood Potteries
9 Advance Rd.
Toronto, ONT M82 2S6
Ernie Doherty

Feldspar Corp.
Box 99
Spruce Pine, NC 28777
(704) 765-9051
E. Clark Jenkins

Ferro Corp.
One Erieview Plaza
Cleveland, OH 44114
(216) 641-8580
Telex: 980165
A. Posnick

Ferro Industrial Products Ltd.
354 Davis Rd.
Oakville, ONT L6J 2X1
(416) 845-4277
Glenn O. Zeller

Fusion Ceramics, Inc.
Box 127
Carrollton, OH 44615
(216) 627-5821
Richard C. Hannon

General Color & Chemical Co., Inc.
Box 7
Minerva, OH 44657
(216) 868-4161
Carl W. Gartner

Hammill & Gillespie, Inc.
Box 104
Livingston, NJ 07309
(201) 994-3650
Telex: 139114
Richard P. Isaacs

Indusmin, Inc.
Box 1445
Columbus, OH 43214
(614) 262-1545
Theodore P. Rahal

Indusmin Ltd.
365 Bloor St. E.
Toronto, ONT M4W 3L4
(416) 967-1900
J. R. Levert

Industrial Metals & Minerals Co.
3189 Washington Pike
Bridgeville, PA 15017
(412) 343-6377
Robert C. Keaney

International Minerals & Chem. Corp.
421 E. Hawley St.
Mundelein, IL 60060
(312) 566-2600
TWX: 910-233-4146
G. Thomas Widger

Jelenko, J. F., & Co.
99 Business Park Dr.
Armonk, NY 10504
(914) 273-8600
Telex: 646336
Ronald J. Leavesley

Keaney, J. C., & Sons, Inc.
Box 14726
Pittsburgh, PA 152340726
(412) 563-1234
Joseph C. Keaney, Jr.

Kings Mountain Mica, Inc.
Box 709
Kings Mountain, NC 28086
(704) 739-3616
Telex: 703063
Matthew A. Ferro, Jr.

Lithium Corp. of America
449 N. Cox Rd., Box 3925
Gastonia, NC 280533925
(704) 867-8371
Telex: 57-5253
H. J. Andrews

Ottawa Silica Co.
Box 577
Ottawa, IL 61350
(815) 434-0188
TWX: 910-642-3702
R. J. Lacke

PDH Inc.
Box 551
Chester, NY 10918
(914) 469-2193
Philip D. Hamling

Pacer Corp.
Feldspar Div.
Box 912
Custer, SD 57730
(605) 673-4419
(TWX: 510-366-8040
David Kruskopf

Particle Processing & Classifying Co
183-195 Railroad Ave., Box 2588
Paterson, NJ 07509
(201) 279-0740
Telex: 144-594
C. B. Marsden

Potters Supply Co.
Box 799
East Liverpool, OH 43920
(216) 385-7474
David M. Irwin

Schweigart Enterprises, Inc.
D/B/A Calspar
12415 Los Nietos Rd., Suite 107
Santa Fe Springs, CA 90670
(213) 944-6108
Hartmut Schweigart

Spartan Minerals Corp.
Box 520
Pacolet, SC 29372
(803) 474-2234
Telex: 57-5253

Steel Brothers Canada Ltd.
1325 Ellice Ave.
Winnipeg, MAN R3G 0G1
(204) 772-0381
F. Pearson

The Pottery Supply House Ltd.
2060 & 2070 Speers Rd.
P.O. Box 192
Oakville, ONT L6J 5A2
(416) 827-1129
Jorgen Poschmann

Whittaker, Clark & Daniels Inc.
1000 Coolidge St.
South Plainfield, NJ 07080
(201) 561-6100
Telex: 71-6858025
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Research Organizations (Feldspathic Minerals)

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Mt. View, CA 94039
(415) 964-3200
TWX: 910-379-6593
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Kumry Rd., Drawer C
Trumbauersville, PA 189700051
(215) 536-0333
Telex: 84-6370
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Alzeta Corp.
500 Clyde Ave.
Mountain View, CA 94043
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Butler, PA 16001
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Argonne National Lab
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2901 Telestar Ct.
Falls Church, VA 22042
(703) 560-3292
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Atlantic Research Corp.
5390 Cherokee Ave.
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201 Lowell St.
Wilmington, MA 01887
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TWX: 710-347-6930
Telex: 947448
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Ball Corp.
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Muncie, IN 47302
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TWX: 810-344-1680
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Bjorksten Research Labs, Inc.
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Madison, WI 53715
(608) 6900
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Broutman, L. J., & Assoc., Ltd.
3424 S. State St.
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Catholic University of America
Vitreous State Lab
B-2 Keane Hall, 620 Michigan Ave.
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Telex: 951-087
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TWX: 710-474-3042
Telex: 965821

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Gorham, ME 04038
(207) 892-2216
Telex: 94-4479
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Heany-Hartsoffe, Inc.
Fairview Dr., Box 38
Scottsville, NY 14546
(716) 889-2700
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IIT Research Institute
10 W. 35th St.
Chicago, IL 60616
(312) 567-4000
TWX: 910-221-5432
M.A.H. Howes

KMS Fusion, Inc.
3941 Research Park Dr., Box 1567
Ann Arbor, MI 481061567
(313) 769-8500
Telex: 23-5237
Alexander J. Glass

Lehigh University
Whitaker Lab No. 5
Bethlehem, PA 18015
(215) 861-4220
Peter Likins

Little, Arthur D., Inc.
25 Acorn Pk.
Cambridge, MA 02140
(617) 864-5770
TWX: 710-320-0820
Telex: 921436
D. William Lee (P)

Midwest Research Institute
425 Volker Blvd.
Kansas City, MO 64110
(816) 753-7600
TWX: 910-771-2128
John McKelvey

National Spectrographic Labs
Div. of Rexham Industrial Div.
7650 Hub Pkwy.
Cleveland, OH 44125
(216) 447-1550
E.A. Mestancik (GM)

Omni Materials Technologies, Inc.
25 Clair Dr., Box 2077
Attleboro, MA 02703
(617) 226-5655
David C. Hill

Ort on, Edward, Jr., Ceramic Foundation
6991 Old 3C Hwy., Box 460
Westerville, OH 43081
(614) 895-2663
Milan Vukovich, Jr.

Remet Corp.
Box 19235
Columbus, OH 43219
(614) 253-5509
Telex: 234488
S.M. Halliday

Rensselaer Polytechnic Institute
Dept. of Materials Engineering
Troy, NY 12181
(518) 270-6373
Robert Doremus (Prof)

SRI International
333 Ravenswood Ave.
Menlo Park, CA 94025
(415) 326-6200
TWX: 910-373-2046
Telex: 334486
William F. Miller

Solar Turbines, Inc.
Sub. of Caterpillar Tractor Co.
Box 85376
San Diego, CA 921385376
(619) 238-5500
TWX: 910-335-2090
Telex: 695-045
J.N. Hanson

Southern Research Institute
2000 Ninth Ave., S.
Birmingham, AL 35255
(205) 323-6592
Telex: 59812
Sabert Oglesby, Jr. (P)

Spectrochemical Labs, Inc.
8350 Frandstown Ave.
Pittsburgh, PA 15221
(412) 371-2345
TWX: 710-644-4439
E.M. DuBois

Structure Probe, Inc.
Box 656, 535 E. Gay St.
West Chester, PA 193810656
(215) 436-5400
Telex: 835367
Charles A. Garber

System Research Labs, Inc.
2800 Indian Ripple Rd.
Dayton, OH 45440
(513) 426-6000
TWX: 810-450-2621
F.J. Russ

Technics, Inc.
2305 Paragon Dr.
San Jose, CA 95131
(408) 946-8700
Telex: 357482
K. Thomas Brandt (P)

Therm, Inc.
Box 220
Ithaca, NY 14851
(607) 572-8500
TWX: 510-255-5875
Robert R. Sprole, II (P)

Thermo Electron Corp.
R&D Center
101 First Ave.
Waltham, MA 02154
(617) 890-8700
Telex: 92-3323
Firooz Rufeh (P)

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Tuscaloosa Research Center
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(205) 758-0491
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Code 6360
Washington, DC 20375
(202) 767-2131
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Valley Assoc., Inc.
Box 160
Alfred Station, NY 14803
(607) 587-8211
Wallace C. Higgins (P)

Vanderbilt University
Dept. of Mech. & Mat'ls Engrg.
Box 1612, Sta. B
Nashville, TN 37235
(615) 322-2413
Telex: 554-323
J.B. Wyatt

Varian Associates
EIMAC Div.
301 Industrial Way
San Carlos, CA 94070
(415) 592-1221
TWX: 910-376-4893
Edward H. Ginzton

Westinghouse Electric Corp.
R&D Center
1310 Beulah Rd.
Pittsburgh, PA 15235
(412) 256-7000
R.E. Kirby

York Services Corp.
Sub. of York Research
One Research Dr.
Stamford, CT 06906
(203) 325-1371
A.J. Kurtz

APPENDIX II

COMPANIES CONTACTED

COMPANIES CONTACTED

A) By Mail

Air Products & Chemicals	Whip-Mix
Advance Process Supply	Mansfield
Bassichis Co.	Pixley-Universal Ceramatec
Bowerston Shale	Pfaudler
Corning Glass Works	Porcelain Enamel Finishers
Coors Porcelain	Porcelain Enamel Inc.
Cotronics Corp.	Porcelain Industries
Dentsply International	Porcelain Metals
Eisenmann Corp.	Regal Ware
Electrical Refractories	Smith, A.O.
Fireline Inc.	Southwestern
Friedrichsfeld BmbH	Inland Enterprises
General Electric	Amphenol Products
Harshaw Chemical	Clevepak Corp.
Hadley Pottery Co.	Diamonte
Koch Engineering	Du-Co Ceramics
Hommel, O.	Ceramic Coating
Jelenko, J.F.	Ceramic Color
Haeger Industries, Inc.	Consolidated Ceramics
Kyocera International	Vitreous Steel
Hall China	Wheeling Pittsburgh
Hartstone	Artesian
Hull Pottery	Eliger Plumbing
International Minerals & Chem.	Gulton Industries
Ilka Ceramics	Heaney
Indiana Glass Co.	IP
Jackson China	Joslyn
Kingswood Ceramics	Ohio Brass
Mayer China	Porcelain Products
McCoy, Nelson Pottery	Saxonburg Ceramics
Newy, J.M.	Roesch
Orthocast Industrial	Union Carbide
Pfaltzgraff	Universal Clay Products
Particle Processing & Class.	Westinghouse Co.
Regal China Corp.	CTS
Reward Ceramic	American Porcelain
Robinson-Ransbottom Pottery	Armco
Royal China	Inland Finishing
Specialty Glass	Artistic Glass
Shenango China	Bent Glass
Sterling China	Globe Amerada
Steuler International	Libbey-Owens
Syracuse China	Shatterproof
Western Stonework	Bausch & Lomb

Nuclear Pacific
Fredericks Co.
Vitrifunctions
Certain-Teed
FIBREX
Goodyear Aerospace
Thompson Eanmel
Ball Corp.
Glenshaw Glass
Northwestern Glass
Independence
Maytag
Reichold Chem.
Fyrepel Products
Nico Fibers
Behrenberg Glass
Brockway Inc.
Dereume, Raymond
Glass Beads
Jeannette Shade
Leco Corp.
Phoenix Glass
Potters Industries
Reliance Glass
Smith
Nilda Ceramics
Sylvester & Co.
Bendix
Amtec Industries
Ceramic Finishing Co.
DFC Ceramics
Dimat
Industrial Ceramic
Murata Precision

Bartlett Collins
Kopp Glass
Brunswick
Eagle-Picher
Fiber Materials
Thomas Industries
Variety Glass
Diamond Glass
Liberty Glass
Ervite Corp.
Jones Metal
Pittsburgh Corning
Overmyer Corp.
Manville Bldg.
PPG Industries
Brockway Tubular Prod.
Crystal Art Glass
Flex-O-Tile
Imperial Glass
KMS Fusion
P.Q. Corp.
Pope Scientific
Pyromatics Inc.
Schott Glass
Latronics Corp.
Pemco Products
AC Spark Plug Div.
Stitt
Astro Metals
Clow Corp.
Dialectric
Honeywell Inc.
Kingswood
Victor Insulators

B) By Visit

Austenal Dental Inc.
Chi-Vit Corp.
Eagle-Picher Industries
Owens-Corning Fiberglas
RCA Corp.
Anchor-Hocking Corp.
Buffalo China
Erie Ceramic Artsco
Lancaster Glass Corp.

Kokomo Sanitary Pottery Corp.
American Art Clay Comp. Inc.
Akron Porcelain & Plastics Comp.
Owens-Illinois Inc.
U.S. Ceramic Tile Co.
Cambridge Tile Mfg. Inc.
Victor Insulators Inc.
Ferro Corp.
Hadley Pottery

C) By Telephone

Independent Porcelain (Alta)
Fiberglas Inc. (Vancouver)
Domglas (Redcliff, Alta)
Fiberglas (Edmonton, Alta)
Norceran Inc. (Ont.)
Maple Leaf Ceramics
Blue Mountain Pottery

Domglas (Vancouver, B.C.)
Consumers Glass (B.C.
Manville (Alta)
Northwest Glass (Seattle, Wash.)
Walltech (Ont.)
Consumer Glass (Ont.)

APPENDIX III

CORNING ENGINEERING'S REPORT

CORNING

Corning Engineering
Laboratory Services
Corning Glass Works
Corning New York 14831
Tel 607-974-6360
Telex 932498 or 99

March 20, 1986

Laboratory Analysis Report for:

Mr. Gary Pearse
Agricola Mineralia
P.O. Box 97
Navan, ONT. K4B1J3

CELS Client No.: 17024-0C
Date Received : 2/25/86
Date Reported : 3/13/86
Approved by DRP

Copy to: CELS File

SAMPLE IDENTIFICATION:

LAB SAMPLE NO.	Sample Description
20744	Glass Grade Feldspar
20745	Lab Melts using Feldspar

ANALYSES REPORTED:

Exhibit	Test Description
A	Lab Melt Information
B	Qualitative Spectrographic Analysis
C	Quantitative Chemical Analysis & Powder Durabili
D	Physical Properties Analysis
E	Liquidus Determination
F	Commentary

COMMENTS:

Client Purchase Order No.

Direct questions regarding this report to Donna Parysek, CELS office

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LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit A: Lab Melt Information

Sample Description: Glass Grade Feldspar, Lab Melts using Feldspa

Lab I.D. No.: 20744-20745

A lab melt of a 012-Type Lead Glass and one of a Soda Lime Flint Container Type Glass were prepared using the feldspar supplied by th client. The batch formula's which were calculated by CELS, using feldspar composition provided by I.M.D. Laboratories, are listed below.

Soda Lime Flint Container		012-Type Lead Glass	
Sand	328 grams	Sand	236.0
Soda Ash	115	Soda Ash	28.0
Calcitic Limestone	85	Potash	53.5
Glass Grade Feldspar	40	Litharge	145.6
Calumite	15	Niter	5.0
Salt Cake	1.2	Glass Grade Feldspar	60.4
		Sodium Antimonate	4.7
Total Batch	584.2	Total Batch	533.2

Theoretical Glass Composition:

Soda Lime Flint Container (Wt.%)		012-Type Lead Glass (Wt.%)	
Al_2O_3	1.8	Al_2O_3	2.1
Na_2O	13.7	Na_2O	4.0
K_2O	0.8	K_2O	8.4
CaO	10.7	Sb_2O_3	0.7
MgO	0.3	PbO	29.1
Fe_2O_3	0.04	SiO_2	55.5
SO_3	0.2	Rb_2O	0.16
SiO_2	72.3		
Rb_2O	0.11		

Both glass batches were melted at 1400 deg. C. for 3 hours, quenche and remelted at 1500 deg. C. for 4 hours. The samples were then quenched and knocked from the crucibles for the analysis.

LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit B: Qualitative Spectrographic Analyses (QSA)

Sample Description: Glass Grade Feldspar

Lab I.D. No.: 20744

Range %	Element Detected (Reported as Oxide)
> 10	SiO_2, Al_2O_3
5 - 20	K_2O
1 - 10	-
0.5 - 5	Na_2O
0.1 - 1	P_2O_5, Li_2O
0.05 - 0.5	CaO
0.01 - 0.1	Ga_2O_3, Fe_2O_3
0.005 - 0.05	MnO_2, MgO
0.001 - 0.01	B_2O_3, PbO, Cr_2O_3, SnO_2
0.0005 - 0.005	TiO_2, CuO
0.0001 - 0.001	Bi_2O_3, Ag

Not Detected - See attached table of elements sought and their detection limits.

LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit B: Qualitative Spectrographic Analysis (QSA)

Commentary on QSA Analysis

1. Elements not sought spectrographically are : C, N, O, F, He, Ne, Cl, Ar, Se, S, Br, I.

2. Detection Limits for Qualitative Analysis:

Detection Limits (%)
(Wt. % as Common Oxide)

Ag	0.0001	Ca	0.01	Ga	0.001	Mo	0.0005	Si	0.001
Al	0.001	Cd	0.01	Ge	0.0005	Na	0.05	Sn	0.0005
As	0.05	Ce	0.05	Hg	0.001	Ni	0.001	Sr	0.01
Au	0.001	Co	0.001	In	0.0005	P	0.1	Ti	0.0001
B	0.001	Cr	0.005	K	1.0	Pb	0.0005	V	0.0005
Ba	0.01	Cu	0.0001	Li	0.01	Pt	0.005	Zn	0.01
Be	0.0005	Er	0.01	Mg	0.0001	Rh	0.001	Zr	0.001
Bi	0.0005	Fe	0.001	Mn	0.0005	Sb	0.01		

3. Precision of the Qualitative Analysis is +/- 1 range % category on this exhibit.

4. Chemical species are determined as elements, but reported as common oxides per glass industry convention.

5. Oxides, e.g., the alkalies, analyzed in more sensitive spectral regions per client request will be specifically identified and respective detection limits will be indicated in the report.

LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit C: Quantitative Chemical Analyses & Powder Durability

Sample Description: Feldspar, Soda Lime Lab Melt, 012 Lead Glass

Lab I.D. No.: 20744-20746

Determination	Results (Wt. %)		
	Feldspar	Soda Lime Lab Melt	012 Lead Glass Lab Melt
Al2O3	16.80	1.65	2.04
Na2O	1.77	13.2	4.05
K2O	10.3	0.86	8.37
CaO	-	10.66	-
MgO	-	0.33	-
Sb2O3	-	-	0.71
Fe2O3	0.084	0.044	0.031
F-	0.040	-	-
Cl-	0.009	-	-
LOI	0.31	-	-
PbO	-	-	28.92
P2O5	0.34	-	-
Rb2O	1.65	0.13	0.19
USP III Powder Durability	-	7.97 ml .02N H2SO4	4.81 ml .02N H2SO4

LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit D: Physical Property Analyses

Sample Description: Lab Melts Using Feldspar

Lab I.D. No.: 20745

Determination	Results	
	SL Type	G12 Type
Softening Point (deg. C)	724	642
Anneal Point (deg. C)	552	450
Strain Point (deg. C)	507	427
Expansion (x10-7/C)	88.7	90.1
Density (gm/cubic cm)	2.4981	3.0355

D-C Volume Resistivity (p) = Resistance x Area/Thickness

Temperature (deg. C.)	Log Resistivity (P), Ohms/Cm	
	SL Type	G12 Type
350	5.555	7.860
250	6.970	9.875

LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit E: Liquidus Determination

Sample Description: 012 Lead Glass

Lab I.D. No.: 20745

1. Liquidus Temperature (24 Hour Furnace Time)

Area	Liquidus (deg. C)
Air Surface	-
Internal Area of Sample	-
Platinum Surface	-

2. Phases and Comments

Devitrification Phase Composition		Composition Identificatio
Primary :	No Obvious Devitrite above low end of the Melt at 670 deg. C.	
Secondary:	-	
Other :	-	

LABORATORY ANALYSIS REPORT

CELS Client No.: 17024-001

Exhibit E: Liquidus Determination

Sample Description: Soda Lime Flint Container

Lab I.D. No.: 20745

1. Liquidus Temperature (24 Hour Furnace Time)

Area	Liquidus (deg. C)
Air Surface	975
Internal Area of Sample	997
Platinum Surface	996

2. Phases and Comments

Devitrification Phase Composition		Composition Identification
Primary :	Beta-Wollastonite	CaO.SiO2
Secondary:	Devitrite	Na2O.3CaO.6SiO2
Other :	-	

Exhibit F: Commentary

Results obtained on the lab melts using your feldspar were comparable to values associated with glasses of similar compositions. The soda lime container composition results appear to be slightly more in line with typical values than the 012 lead glass composition results. The table below lists typical values for these compositions, with the results of your melts in parentheses:

	Soda Lime Container		012 Lead	
Softening Point (deg. C.)	724	(724)	630	(642)
Anneal Point (deg. C.)	550	(552)	435	(450)
Strain Point (deg. C.)	508	(507)	395	(427)
Expansion (x10-7/C)	89.8	(88.7)	89.5	(90.1)
Density (gm/cubic cm)	2.50	(2.4981)	3.05	(3.0355)
Liquidus (deg. C.) (average)	980	(975)	760	(none)
D-C Volume Electrical Resistivity (250 deg. C.)	(6.970)	6.6	(9.875)	10.1
(350 deg. C.)	(5.555)	5.3	(7.860)	8.0

Liquidus determinations on lead glasses are difficult because the devit phases tend to be very sparse and hard to isolate; therefore, it is not unusual that crystals were not found in your sample.

The USP III Powder Durability results obtained on your samples were i spec with the 8.5ml .02N H2SO4 limit set for soda lime glasses. Durability specifications for lead glass were not available, however the results for the lead glass are significantly lower than soda lime glass which is expected.

The most notable change would appear to be associated with the low temperature physical properties (softening, anneal and strain points) of the lead glass. All three measurements are higher than normal on your glass melt, presumably due to the rubidium content. The significance of this change in a lead glass composition may, or may not, be positive. Dependant on the controlling operating parameters in a given lead glass melting and forming operation, one would have t assess whether higher glass forming temperatures would be desirable.

Overall, no significant change occurred with the sode lime glass properties.

In terms of glass batch meltability, the batches employing your feldspar material were not observed to behave any differently during melting than conventional glass batches of the same types of glass.