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REPORT OF INVESTIGATIONS

ON

PRODUCTION OF ALUMINA AND ALKALIES FROM NEPHELINE SYENITE

By

F. R. Archibald,
Research Chemist, Ventures Limited.

For:

THE AMERICAN NEPHELINE CORPORATION,
THE ALUMINUM COMPANY OF CANADA, LIMITED,
and the
BUREAU OF MINES,
DEPARTMENT OF MINES AND RESOURCES,
Ottawa, Canada.

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CONTENTS

Introduction:

Recovery of alumina from clays and silicate rocks has long been a subject for speculation and patent application. With the exception of operations in Russia and small-scale operations in Germany and Norway, such a project does not appear to have been seriously undertaken and carried through to plant production.

Nepheline syenite, which occurs in large quantities in the Bancroft and Haliburton areas of Ontario, seemed to offer more possibilities in this direction than most other silicate rocks. Experimental work on the subject was first undertaken for the American Nepheline Corporation in September, 1937, at the ore dressing laboratories of Beattie Gold Mines (Quebec) Limited, Duparquet, Quebec. The investigation was continued at irregular intervals until March, 1939, when a more intensive program of test work was instituted. The earlier work was concerned largely with acid processes, and, except as a background, is of little interest.

Development of the alkaline process, using limestone from the same locality as the nepheline syenite occurrences, dates from the summer of 1939, since which time it has passed from the laboratory to the small pilot plant stage. From August, 1940, to the present, the investigation has been carried out in the laboratories of the Bureau of Mines in Ottawa; and under the joint sponsorship of the American Nepheline Corporation and the Aluminum Company of Canada. The working space and much of the equipment has been supplied by the Bureau of Mines, whose chief and staff have given most valuable help and co-operation.

Exploration and development of the nepheline syenite deposits in the Bancroft, Haliburton and Lakefield areas had been carried out for several years prior to 1939 by the American Nepheline Corporation in connection with their production of nepheline syenite as an industrial mineral. Since that time the diamond drilling and exploration work has also been undertaken jointly with the Aluminum Company of Canada.

Acknowledgment:

On behalf of the companies associated in this investigation, the author expresses sincere appreciation to Mr. W. B. Timm, Director, Mines and Geology Branch, Department of Mines and Resources, and to Mr. C. S. Parsons, Chief, Metallic Minerals Division, and his staff for their co-operation and help throughout this investigation.

SUMMARIES.

General Summary:

In brief, the conclusions drawn from the results of our metallurgical investigation, exploration of ore reserves, and economic considerations are:

(a) That a comparatively simple metallurgical process has been developed and demonstrated for recovery of alumina and alkalies from nepheline syenite and other siliceous ores of aluminium.

(b) That, although the tonnage of high-grade nepheline rock (over 30% Al_2O_3) is not large, there are very large tonnages containing 24% Al_2O_3.

(c) Under normal circumstances, on the basis of cost per ton of alumina produced, the process as applied to nepheline syenite of the grade available in quantity, could not compete with production from bauxite. On a large-scale operation (1,000 tons Al_2O_3 per day) it has been estimated that the production cost, before write-off for depreciation and taxes, would be approximately $43.00 per ton of Al_2O_3.

In the larger aspect of rendering our aluminium industry independent of foreign sources of raw materials, the process as applied to nepheline syenite has significance beyond straight economic considerations. In this connection it is noted:

(1) The nepheline syenite deposits of the Bancroft and Haliburton areas are believed to furnish the only feasible source of alumina within Canada that could supply her large aluminium industry with raw material.

(2) If the project were undertaken on any appreciable scale, the production of potash would more than replace Canadian imports for fertilizer purposes and would provide the potash as carbonate which is preferred over chloride and sulphate. In this way Canada could, in one operation, be made independent of imports of two of her most strategic materials, for both of which she is now entirely dependent.

(3) The production of soda ash would relieve present shortages and would make large tonnages available for uses to which it would now be put if available at low cost. Desulphurization of iron and steel is one example.

(4) The production of soda ash would fit in with lime-soda treatment of low-grade bauxite or kaolin. It is quite evident that lower grade bauxite is necessarily going to be used in the production of alumina, and it would seem reasonable that in a time of emergency, the additional soda

required for bauxite treatment in a rapidly expanding aluminium industry, might better come from an operation that produces alumina as well.

The four topics discussed above are of particular interest from the Canadian viewpoint. If we consider the situation as it applies to the United States as well, we may add further:

(5) The estimated bauxite reserves of the United States in September, 1941 (U.S. Bureau of Mines Report R.I. 3598) were given as 9,343,000 long tons of 55 per cent plus grade; that is, the grade required by Bayer process plants. When treatment of lower grade material is undertaken, it is believed that a modification of the lime-sinter process will be found most suitable, or a combination of soda and lime processes. Our experience may be of considerable value in exploration of this problem.

(6) Total United States bauxite reserves, 30 per cent grade or better, were estimated at 29,028,000 long tons, of which 27,254,000 tons are in Arkansas, a long distance from supplies of soda ash. Since the Arkansas bauxite has apparently been derived from nepheline syenite and extensive bodies of the latter probably still occur, our process may have particular application here. The lime-sinter process for production of alumina and alkalies from nepheline syenite would fit in as a complementary process. In treatment of low grade Arkansas bauxite, the soda required by the one would be produced in the other.

(7) With respect to treatment of kaolin we have already done laboratory test work on Georgia kaolin and found the lime-sinter method applicable. No estimate of grade and

tonnage possibilities being available, it is impossible to estimate the importance of this material in the aluminium ore picture.

In summary, it may be repeated that the lime-sinter process, applied to nepheline syenite can provide a purely Canadian source of alumina and potash, two important materials for which we are entirely dependent on imports. The production of soda ash would relieve present shortages and provide for increased consumption in treating low grade bauxite. The process has been demonstrated as workable and the rock reserves are large. The process itself may be of interest to United States authorities in furthering their avowed purpose of making the continent self-sufficient in aluminium.

Summary of Grades and Reserves of Raw Material:

The following summary, based on surface exploration and diamond drilling results, has been prepared by N. H. C. Fraser. The subject has been enlarged upon in a later section of this report. (Page 27).

> The diamond drilling which has been done in the various areas was of an exploratory nature and not intended to delineate tonnage of any particular grade. The only tonnage calculations, therefore, which can be made are of tonnages of a particular grade which might possibly be obtained. The tonnage calculations in this report are of this nature. A fairly large amount of diamond drilling would have to be done to test these possibilities in lateral and vertical extent. Detailed drilling, with holes at close intervals, would be required.
>
> The exploratory program carried out, however, provides ample information as to the general character of the nepheline deposits. Thus, the tonnages of grades better than 24% Al_2O_3 appear to be somewhat limited. At 24% grade, however, the tonnage possibilities are very large. This applies more especially to the Bancroft Nepheline area where the average grade approximates this figure.

In the Davis Hill area of the Bancroft deposit, it is estimated that 15,000,000 tons of rock grading 24% Al_2O_3 could be obtained above valley level. For a vertical extent of 500', which is roughly the maximum vertical extent explored in the drill holes, a tonnage of at least 50,000,000 would be available. In the Cooney Hill area of the Bancroft deposit, the grade appears to be slightly lower than in the Davis Hill area, probably lying between 23% and 24% Al_2O_3 . The tonnage of this grade lying above valley level is estimated at 5,000,000 tons. For a vertical extent of 500' probably 20,000,000 would be available.

In the York River area the average grade of the nepheline rock is lower than in the Bancroft area. The tonnage possibilities of 24% rock are not very large in this area, but, accepting a grade of 21% Al_2O_3, which is closer to the average grade, a tonnage of 60,000 tons per slope foot could be obtained. To a depth of 500', there would be 30,000,000 tons.

The ground explored both in the York River and Bancroft Nepheline areas are but small parts of these large deposits, and hence the tonnages given above undoubtedly could be expanded several times by further exploration.

Although the reserves of nepheline rock in the Bancroft district are very large, and additional sources might not be required, two other areas of nepheline rocks in Southwestern Ontario are worthy of mention since tremendous additional tonnages could be obtained from them, if necessary. In the vicinity of Gooderham, in Haliburton county, nepheline rock similar in character to that in the Bancroft district is extensively developed. Undoubtedly, grades and tonnages comparable to those of the Bancroft district would be found in this occurrence. Near Lakefield in Peterborough country a tremendous volume of nepheline rock lies in a range of hills called the Blue Mountains. This deposit is roughly seven miles in length and ranges from ¼ to 1½ miles in width. A detailed study of the nepheline-bearing mass has shown that in its average composition it carries 23% Al_2O_3 and 58 to 60% SiO_2.

The situation with respect to limestone is considered reasonably good. Details will be found in a later section of this report.

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PRODUCTION COSTS OF PRODUCING Al_2O_3 AND ALKALIES FROM NEPHELINE SYENITE AND KAOLIN.

	Production cost per ton Al_2O_3 before credits for alkalies. Operating costs only.	Production cost per ton Al_2O_3 after credits for alkalies. Operating costs only.
Case 1 - 100-ton-capacity plant to produce 8.35 tons per day Al_2O_3 from York River rock, 28% Al_2O_3.	$ 103.86	$ 80.00
Case 2 - 18,250-ton-capacity plant treating 24% alumina, Bancroft rock to produce 1,000 T.P.D. of Al_2O_3.	73.91	43.91
Case 2-A - 17,020-ton-capacity plant treating Bancroft rock - 24% Al_2O_3 and treating limestone by flotation.	72.36	42.36
Case 3 - 18,420-ton-capacity plant treating 21% alumina York River rock to produce 1,000 T.P.D. of Al_2O_3.	78.16	52.45
Case 4 - 10,698-ton-capacity plant to treat 39% alumina Kaolin to produce 1,000 T.P.D. of Al_2O_3.	44.39	No credits for alkalies loss in soda ash.

NOTE: In Case 2-A, the benefit of flotation is greater than shown in the table in that limestone of 83.5% grade would be quarried as against 89.5 in Case 2, thus simplifying quarrying and enlarging reserves.

PRODUCTION Al_2O_3 AND ALKALIES FROM NEPHELINE SYENITE AND KAOLIN

ESTIMATED PLANT COSTS AND POWER REQUIREMENTS.

	Mill cost	Mining plant	Mill Power	Mine Power	Total power
	$	$			
Case 1 100-ton plant on York River Rock.	495,500.00	contracted	510	contracted	510
Case 2 18,250-ton-capacity plant treating 24% Bancroft rock to produce 1,000 T.P.D. Al_2O_3.	54,540,000.00	$ 1,850,000.00	Power consumed 0.63 H.P. per ton milled 11,453	2,550	14,003
Case 2A 17,020-ton-capacity plant treating Bancroft rock to produce 1,000 tons Al_2O_3 and treating limestone by flotation.	51,060,000.00	1,850,000.00	10,722	2,400	13,122
Case 3 18,420-ton-capacity plant treating York River rock containing 21% Al_2O_3 and producing 1,000 T.P.D. Al_2O_3.	55,260,000.00	1,850,000.00	11,604	2,600	14,204
Case 4 10,698-ton-capacity plant treating Georgia Kaolin to produce 1,000 T.P.D. Al_2O_3.	32,094,000.00	1,100,000.00	6,740	1,500	8,240

NOTE: Milling plant costs for large tonnage plants calculated on a basis of $3,000.00 per ton milled. Milling power estimate based on large tonnage copper concentrations and mining power estimate based on open pit mining operations with churn drilling.

DETAILS OF ESTIMATED PRODUCTION COSTS.

Case 1.

100 T.P.D. plant (To treat:
(York River rock of 28% grade.
(Havelock limestone.
(Plant located at Lakefield, both raw
(materials supplied by contract.

Analyses		Nepheline	Limestone
Al_2O_3	-	28.0	-
SiO_2	-	42.8	2.8
Na_2O	-	12.0	-
K_2O	-	4.0	-
$CaCO_3$	-	-	94.3
Net $CaCO_3$	-	-	85.0

Rock quarried: (37.3 tons nepheline rock
(62.7 tons limestone
74.0 tons sinter product

Production:	8.35 tons Al_2O_3; 12.77 tons $Al_2O_3.3H_2O$ @ $52 per ton	$ 664.04
80% extraction	5.76* tons Na_2CO_3 @ $20	115.20
	1.75 " K_2CO_3 @ $48 (2.34 tons of 75%)	84.00
	Total credits	$ 863.24
	" " per ton quarried	8.63

Production Costs:

Quarrying and hauling 37.3 tons nepheline to Bancroft @ $3.00 per ton (by contract)	$ 111.90	
R.R. freight, Bancroft to Lakefield @ $1.50 per ton	55.95	
Stock piling and reclaiming nepheline @ 20 cents	7.46	
62.7 tons limestone purchased and delivered to Lakefield @ $2.00 per ton	125.40	
Stockpiling and reclaiming limestone @ 20 cents	12.54	
Crushing and grinding, 100 tons @ 60 cents	60.00	
Pelletizing and sintering, mechanical @ 25 cents	25.00	
Fuel at $7.00 per ton; 600 lbs. per ton sinter = 22.2 tons coal per day	155.40	
Leaching and solution treatment at $2.50 per ton of sinter	185.00	
Administration and general @ 50 cents per ton quarried	50.00	
Waste disposal, 68 tons (including 8% moisture) @ 10 cents	6.80	
Packaging, loading and shipping, 20.87 tons @ $2.00	41.74	
Control, laboratory and research	30.00	
Total production cost per day	$ 867.19	
Cost per ton quarried	$	8.67
Operating loss per day	3.95	
" " " ton quarried		.04
Production Cost per ton Al_2O_3 without Alkali Credits	$ 103.86	
" " " " " with " "	80.00	

* NOTE: The production of soda is reduced to this figure to allow for loss due to imperfect separation from potassium carbonate in the scheme proposed.

Case 2.

1,000 tons Al_2O_3 per day from Bancroft rock @ 24% Al_2O_3.

Analyses:		Nepheline	Limestone
Al_2O_3	-	24.0	-
Na_2O	-	10.5	-
K_2O	-	5.7	-
SiO_2	-	50.0	7.0
$CaCO_3$	-	-	89.7
Net $CaCO_3$	-	-	66.4

Rock quarried: 18,250 tons total rock.
5,200 " nepheline rock.
13,050 " limestone.

Total 18,250 tons rock quarried.
Sinter produced: 13,100 tons sinter.

Production:

1,000 tons Al_2O_3 per day	
672 tons Na_2CO_3 @ \$20.00 per ton	\$ 13,440.00
345 tons K_2CO_3 @ \$48.00	16,560.00
Total gross return credit for alkalies	\$ 30,000.00
Gross return per ton of rock quarried	1.64

Production Costs:

Quarrying and hauling 5,200 tons nepheline syenite, Bancroft to mill at 50 cents per ton	2,600.00	
Quarrying 13,050 tons limestone at 40 cents	5,220.00	
Stock piling and reclaiming 18,250 tons @ 10 cents	1,825.00	
Crushing 18,250 tons at 6 cents	1,095.00	
Grinding 18,250 tons at 30 cents	5,475.00	
Pelletizing and sintering - mechanical at 10 cents	1,825.00	
Fuel @ \$7.00 per ton; 450 lbs. per ton sinter, 2,948 tons coal	20,636.00	
Leaching and solution treatment, 13,100 tons @ \$2.00	26,200.00	
Calcining 1,000 tons Al_2O_3 @ \$2.50 per ton	2,500.00	
Administration and general, including local taxes at 18 cents per ton quarried	3,285.00	
Waste disposal, 12,000 tons, including 8% moisture, at 5 cents	600.00	
Loading, shipping and packaging:		
1,000 tons Al_2O_3 at 20 cents	200.00	
672 tons Na_2CO_3 at \$2.00	1,344.00	
460 tons of 75% K_2CO_3 @ \$2.00	920.00	
Laboratory control and research at 1 cent per ton quarried	182.50	
Total production costs	\$ 73,907.50	
" " " per ton quarried	4.05	
Production cost per ton Al_2O_3 before credits		73.91
Alkali credits per ton quarried	1.64	
Production cost per ton quarried after alkali credit	2.41	
Production cost per ton Al_2O_3 after credits but before write off		43.91

Case 2A.

1,000 tons Al_2O_3 per day
Bancroft rock at 24% Al_2O_3
Limestone @ 83.5% $CaCO_3$, quarried and floated before use.

Same as Case 2 except for beneficiation of limestone.

Analyses: Nepheline: 24% Al_2O_3; 50.0% SiO_2
Crude Limestone: 83.5% $CaCO_3$; 10% SiO_2

Estimated flotation recovery:

	Wt.	% $CaCO_3$	% SiO_2	Net CaO_3
Heads	100.0	83.5	10.0	
Product	84.7	95.0	3.0	85.0
Rejects	15.3	20.0	48.7	

Nepheline rock, 5,200 tons @ 50.0% SiO_2 = 2,600 tons SiO_2
Concentrate required = 10,200 tons per day.

Rock to quarry = 5,200 tons nepheline rock
12,000 tons crude limestone
17,200 tons total rock.
Sinter made = 12,190 tons.

Production:

1,000 tons Al_2O_3 per day

672 tons Na_2CO_3 @ $20 per ton	$ 13,440.00
345 tons K_2CO_3 @ $48	16,560.00
Total gross return credit for alkalies	30,000.00
Gross return per ton quarried	1.74

Production Costs:

Quarrying and hauling 5,200 tons nepheline rock, Bancroft to mill @ 50 cents	2,600.00
Quarrying 12,000 tons crude limestone @ 30¢	3,600.00
Grinding and floating 12,000 tons limestone @ 30¢	3,600.00
Filtering and drying 10,200 tons product @ 20¢	2,040.00
Stockpiling and reclaiming 17,200 tons @ 10¢	1,720.00
Crushing 17,200 tons @ 6 cents	1,032.00
Grinding 15,400 tons kiln feed @ 25¢ (limestone already partly ground)	3,850.00
Pelletizing, sintering and mechanical, 15,400 tons @ 10 cents	1,540.00
Fuel @ $7.00 per ton; 450 lb. per ton sinter = 2,743 tons	19,201.00
Leaching and solution treatment @ $2.00	24,380.00
Calcining 1,000 tons Al_2O_3 @ $2.50	2,500.00
Administration and general, including local taxes @ 18 cents per ton quarried	3,096.00
Waste disposal, 11,200 tons (including 8% moisture) @ 5 cents	560.00
Loading, shipping and packaging:	
1,000 tons Al_2O_3 @ 20 cents	200.00
672 tons Na_2CO_3 @ $2.00	1,344.00
460 tons of 75% K_2CO_3 @ $2.00	920.00
Laboratory control and research @ 1 cent per ton quarried	172.00
Total production cost per day	72,355.00
" " per ton quarried	4.21

Production cost per ton Al_2O_3 without alkali credits	72.36
Alkali credits per ton quarried:	
Production cost per ton Al_2O_3 with alkali credit before write off	42.36

Case 3.

York River rock - 21% grade.

Analyses:

	YR 1	YR 2	YR 3	Average
Al_2O_3	21.84	20.99	20.76	21.2
Fe_2O_3+TiO_2	10.00	10.11	10.06	10.1
SiO_2	42.18	42.80	41.90	42.3
Na_2O	8.18	7.84	8.08	8.0
K_2O	4.05	4.84	3.67	4.2
CaO	estimated			10.0⊕

Production:

1,000 tons Al_2O_3 per day.
587 tons Na_2CO_3 (645 less 58 in K_2CO_3 product)
291 tons K_2CO_3, 388 tons of 75% grade.

Rock quarried:	5,900 tons nepheline rock
	13,520 tons limestone
Total	18,420 tons quarried
Sinter	13,480 tons

Credits:

587 tons Na_2CO_3 @ $20.00	$ 11,740.00
291 tons K_2CO_3 @ $48.00	13,968.00
Gross return per day	25,708.00
Per ton of rock quarried	1.40

Production Costs:

Quarrying and hauling 5,900 tons nepheline rock to mill @ $1.00	5,900.00
Quarrying 12,520 tons crude limestone @ 40 cents	5,008.00
Stockpiling and reclaiming 18,420 tons @ 10 cents	1,842.00
Crushing 18,420 tons @ 6 cents	1,105.20
Grinding 18,420 tons @ 30 cents	5,526.00
Pelletizing and sintering - mechanical @ 10 cents	1,842.00
Fuel @ $7.00 per ton; 450 lbs. coal per ton of sinter, 3,030 tons coal	21,210.00
Leaching and solution treatment of 13,480 tons @ $2.00	26,960.00
Administration and local taxes at 18 cents per ton quarried	3,315.60
Waste disposal 11,440 tons plus 8% moisture, @ 5 cents	617.50
Calcining 1,000 tons Al_2O_3 @ $2.50	2,500.00

⊕ The CaO content is not credited in this estimation in view of the high ferromagnesian mineral content. A good part of it, and perhaps all would serve in the process in place of added limestone but actual tests have not been made on this grade of rock.

Loading, shipping and packaging:		
1,000 tons Al_2O_3 @ 20 cents	$ 200.00	
587 tons Na_2CO_3 @ $2.00	1,174.00	
388 tons K_2CO_3 of 75% grade @ $2.00	776.00	
Laboratory control and research @ 1 cent per ton quarried	184.20	
Total production cost	78,160.50	
Production cost per ton Al_2O_3 before credits for alkalies		78.16
Credit for alkalies	25,708.00	
Production cost per ton Al_2O_3 after credits for alkalies		52.45
Cost per day after alkali credits	$ 52,452.50	

Case 4.

Georgia Kaolin.

Analyses:

Al_2O_3	38.97	Limestone:	$CaCO_3$	93.0
SiO_2	43.23		SiO_2	2.0
Na_2O	0.15		$CaCO_3$	86.3%
K_2O	0.09			

Limestone 250 miles from kaolin deposits.

Production: 1,000 tons Al_2O_3 per day.

Rock quarried:	3,208	tons kaolin
	7,490	tons limestone
Total rock	10,698	tons
Sinter	7,638	

Production Costs:

Mining 3,208 tons kaolin per day @ 25 cents	$ 802.00	
Transportation 3,208 tons, 250 miles to limestone, at $2.00	6,416.00	
Quarrying 7,490 tons limestone @ 40 cents	2,996.00	
Stockpiling and reclaiming 10,698 tons @ 10¢	1,069.80	
Crushing 10,698 tons @ 5 cents	534.90	
Grinding 10,698 tons @ 25 cents	2,874.50	
Pelletizing and sintering @ 10 cents	1,069.80	
Fuel @ $4.00 per ton, 450 lbs. per ton sinter, 1715 tons coal	6,860.00	
Leaching and solution treatment at $2.00	15,276.00	
Calcining 1,000 tons Al_2O_3 @ $2.50	2,500.00	
Administration and local taxes @ 18 cents per ton quarried	1,925.00	
Waste disposal, 7,150 tons @ 5 cents	357.50	
Soda ash consumption - 1.0% of residue weight 70 tons per day @ $20.00	1,400.00	
Loading, shipping and packaging 1,000 tons Al_2O_3 at 20 cents	200.00	
Laboratory control and research @ 1¢ per ton	106.98	
Total production cost	44,388.48	
Production cost per ton of Al_2O_3		44.39
Cost per ton rock	4.15	

Contents of Section.

GENERAL ACCOUNT OF METALLURGICAL STUDIES.

GENERAL ACCOUNT OF METALLURGICAL STUDIES.

Description of the Process:

(a) Raw Materials and Their Preparation.

The raw materials required are nepheline syenite and high-grade calcium limestone. No other reagents or material, except fuel, are essential. Any silicate rock in which the alkalies and alumina are in equimolecular proportions may be used (albite, for example), but in general the alumina content is too low in rocks that do not contain a goodly percentage of nephelite. Pure nephelite from the Bancroft area contains 34 per cent alumina; the rock that has been used in most of the investigation is diluted with feldspar and contains 30 per cent alumina.

If rocks or materials such as kaolin which contain little or no alkali are used, the process requires some variations from that applied to nepheline syenite.

For the limestone, it is important that the magnesia and silica contents should be low. Here, as in the cement industry, it will no doubt prove advantageous to improve and stabilize the grade of quarried limestone by flotation.

The nepheline rock and limestone are crushed, blended in proper proportion, and together ground to such fineness that 80 per cent passes a 200-mesh screen. If dry grinding has been employed, the mixture is wetted slightly and rolled in a drum or mixer until it has formed into pellets or nodules. If the grinding has been wet, the drying and pelletizing operations may be performed in a rotary dryer.

(b) Sintering.

The pelletized rock mixture is furnaced at a temperature not exceeding 2400° F. and allowing such time that the furnace discharge is shrunken in volume, darkened to a greenish brown colour, and showing evidence of incipient fusion. A rotary kiln has been used for this purpose in the large-scale test work.

(c) Leaching.

The sintered material is crushed and ground to a size that will permit satisfactory handling of pulps, at least through 14 mesh. It is leached in a countercurrent cycle using solution from a previous cycle and that has been impoverished of alumina and diluted to the required alkali content before re-use. In the final stage of leaching, the solution is brought to a concentration of 80 to 100 grams Al_2O_3 per litre.

(d) Desilication.

The final leaching solution is treated in pressure equipment to reduce the silica content within the required limits.

(e) Recovery of Alumina.

The alumina is removed from the solution by combined application of seeding and carbonation with CO_2 gas. The latter may be recovered from the kiln gases. The alumina hydrate is filtered off from the impoverished solution, washed, dried, and calcined to Al_2O_3.

(f) Recovery of Alkalies.

Since there will be a quantity of alkali oxides removed from the sinter in about equimolecular proportions to the alumina removed, there will be an excess of alkalies from each cycle of operation. It will be necessary to divert part of the solution for alkali recovery, and the part that is diverted will necessarily be freed completely of alumina by further carbonation. The portion of impoverished solution that is returned to the leaching circuit will necessarily be diluted with wash water to adjust the alkali concentration. The portion that is diverted for alkali recovery will contain sodium carbonate, potassium carbonate, and some sulphate. The latter is derived from the sulphur content of fuel used in burning.

The solution will be concentrated to a point where crystallization of sodium carbonate monohydrate occurs, then evaporated further in vacuum crystallizing pans for removal of this salt. It should be possible to leave potassium carbonate in solution so that it can be recovered sufficiently pure for fertilizers by drying the whole solution, after removal of the sodium carbonate monohydrate. The potassium carbonate will probably contain up to 20 per cent sodium carbonate and a proportion of sulphate. For production of pure potassium carbonate, further processing would be required.

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Chemistry of the Process:

The process may be applied to a number of aluminous raw materials, such as kaolin, low-grade bauxite, or feldspar, but for our present consideration we shall confine our discussion to nepheline rocks. The term Nepheline Syenite is applied to mixtures of nephelite and feldspars. Such rocks ordinarily carry as accessories varying proportions of ferro-magnesian minerals. Nepheline syenite is considered the most promising of the aluminous silicate rocks for the purposes under consideration, for the following reasons:

(a) The high Al_2O_3 content relative to SiO_2.
(b) The high alkali content.
(c) The ease of decomposition.
(d) The usual close proximity to limestone deposits.

Pure nephelite has essentially the composition $Na_2O.Al_2O_3.2SiO_2$. Part of the soda is replaced by potash but, since the reactions are similar, the illustration is based on soda alone.

The reactions involved in the sintering are:

(1) $CaCO_3 \longrightarrow CaO + CO_2$.

(2) $4CaO + \underset{\text{(nephelite)}}{Na_2O.Al_2O_3.2SiO_2} \longrightarrow \underset{\text{(sodium aluminate)}}{2NaAlO_2} + \underset{\text{(dicalcium silicate)}}{2(2CaO.SiO_2)}$

During leaching, the sodium aluminate dissolves. In order to prevent hydrolysis, the leaching solution is maintained at considerable strength in alkali. In starting an operation it is necessary to use a soda ash solution but after the first cycle is completed the alkali is supplied in the process itself.

The mechanisms of silica removal and seeding of alumina hydrate are more physical than chemical in nature. The chemical results of seeding and carbonation are represented by the following:

(3) $2NaAlO_2 + 4H_2O \longrightarrow Al_2O_3 \cdot 3H_2O + 2NaOH$ (alumina hydrate)

(4) $2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$.

Equipment:

The crushing and grinding of rock and sinter requires nothing other than standard equipment used in mining and metallurgical industries.

The sintering operation is essentially similar to cement burning except that the temperatures are lower and the product contains less fused material; it is a "sinter" rather than "clinker".

The leaching operation requires vessels and equipment resistant to alkalies. Iron is a satisfactory material.

The pressure digestion, seeding, and treatment of alumina hydrate requires specialized equipment but nothing more difficult than that required by the Bayer process for treatment of bauxite.

The concentration and recovery of alkali carbonates from solutions as simple as those produced in this process should not be particularly difficult.

Products:

(1) The chief product of the operation will be alumina hydrate (or calcined alumina). Analysis of hydrate produced in the laboratory showed the following composition:

Loss on ignition - 35.74 per cent (water).

SiO_2	-	0.035 per cent
Fe_2O_3	-	0.0065 "
TiO_2	-	0.0058 "
Na_2O	-	0.37 "

Material produced in the pilot plant was of similar composition (SiO_2, 0.0345 per cent), so that we should be able to meet specifications at least as rigid as indicated by the above analysis.

(2) Second in importance as to quantity produced will be sodium carbonate. There should be no difficulty in equalling the purity of present commercial grade.

(3) Potassium carbonate is produced in amount equalling 1/4 to 1/2 of the soda ash production, dependent on the source of rock. If used for fertilizer manufacture it is likely that the grade noted above will be satisfactory, that is, a potassium carbonate product containing, as impurities, up to 20 per cent sodium carbonate and some sulphate.

(4) Dicalcium silicate residue.

A large tonnage (approximately 60 per cent of the tonnage of rock quarried) will be left after leaching. The composition of this material is approximately as follows:

		Per cent
CaO	-	60
SiO_2	-	32
Al_2O_3	-	2.8
Fe_2O_3	-	4.0
$Na_2O + K_2O$	-	1.0

Possible uses for this product are:

(a) Raw material for cement manufacture. By reburning this residue without further additions a clinker can be produced which on grinding has the properties of Portland cement. Whether it would meet specifications for building purposes has not been investigated.

(b) A soil-conditioning agent to replace "agricultural lime". In the soil, the lime content would become available for neutralizing soil acidity. The lime (CaO) content is 60 per cent for this material as compared with 50 to 54 per cent for agricultural lime.

(c) Dicalcium silicate has a high melting point and the residue might have value as a material for making refractory furnace linings.

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Pilot Plant Operation:

As the process consists of two rather distinct operations, it has been developed from the laboratory scale in two stages. The division permits separate consideration of: (1) preparation of rock materials and furnacing; and (2) leaching and recovery of products.

(1) Furnacing.

The furnacing operation has been developed from batch tests carried out in a muffle furnace, to continuous operation in a rotary kiln with a capacity of 1,500 pounds of rock mixture per day. The kiln, 16 inches in diameter and 12 feet long has been operated for periods as long as two weeks without serious mechanical trouble and producing sinter giving average alumina extraction of over 82 per cent in laboratory leaching tests. For some shifts the extraction exceeded 87 per cent and there is reason to believe that in a larger-scale operation the better figure could be maintained.

(2) Leaching and Recovery of Products.

All steps of the process have been carried out on pilot plant scale except the recovery of alkalies from solutions. This last step should not involve very great difficulty; it has been practised in earlier application of the Bayer process. The added feature of separation of sodium and potassium carbonates is now under study but does not constitute a vital step in the production of alumina. The procedure and results of laboratory tests have been closely duplicated in the pilot plant with respect to regulation of composition and maintenance of cyclic flow of solutions, and the grade of alumina produced. Although pilot plant extraction has fallen about 7 per cent short of laboratory results, it is believed that this is due to lack of complete continuity in the agitation, filtration and washing steps. This lack of continuity necessarily existed in the pilot plant due to limitations in equipment.

In laboratory tests on sinter freshly burned in the pilot plant kiln, 86.5 per cent of the alumina content of the nepheline rock has been extracted. The average for 13 shift samples was 83.0 per cent.

In the small leaching test plant at Ottawa, the extraction was 75.4 per cent. It is considered likely but not certain that a larger plant, operating continuously, should give results duplicating laboratory extraction.

In the desilication step, 3 to 6 per cent of the alumina is carried down in the silicate mud. In the operation for alkali recovery from part of the solution impoverished by seeding, about 3.6 per cent of the alumina (original) is recovered as hydrate containing silica up to 1 per cent. In order to recover the alumina from these two low-grade products they will necessarily be returned to the furnace.

The best net extraction and recovery of alumina, containing less than 0.05 per cent SiO_2, that can be foreseen is 80 per cent of the original rock content. Initial operation would probably not yield better than 73 per cent.

In laboratory tests, the percentage extraction of alkalies has followed the extraction of alumina in completeness. The recovery of alkalies is complicated by volatilization in the kiln. Alkali recovery, in order to equal the percentage recovery of alumina, will demand efficient dust collection.

Although individual tests have been done on lower-grade material, the process has been developed using nepheline rock containing 30 per cent alumina from the Bronson property.

Although it cannot be claimed that all of the problems have been answered, it can be said with certainty that alumina and alkali carbonates can be recovered from nepheline syenite by a comparatively simple metallurgical process and to the degree indicated in the foregoing summary.

Present State of the Investigation:

Excluding actual recovery of alkali carbonates from solution, all steps of the process have been demonstrated on a laboratory scale and in a pilot plant treating 1,500 pounds of rock per day.

Plans for a larger plant to treat 100 tons rock per day are now well advanced.

Sufficient solution from pilot plant operation is on hand for investigation of the recovery and separation of sodium and potassium carbonates.

Should it be decided that plans for a commercial undertaking are to be completed and the project put into operation, it will be important that laboratory investigation should be continued and intensified.

In consideration of the extent of experimental work done by the Russians in investigation of this project before undertaking large-scale production, it is obvious that a great deal more of preparatory work could and should be done in the interval between laying of plans and completion of construction.

The Process as applied to Clay, Kyanite and other Aluminous Materials:

The process has been demonstrated, on a laboratory scale, as applicable to kaolin and kyanite in a series of tests conducted in the American Nepheline Corporation laboratory at Rochester, N. Y., using clay from Georgia and kyanite from North Carolina. Analyses of the raw materials were as follows:

		Kaolin, per cent	Kyanite, per cent
Al_2O_3	-	41.48	61.4
SiO_2	-	42.01	37.7
Fe_2O_3	-	0.30	0.25
CaO	-	0.60	0.07
MgO	-	0.47	0.03
Alkalies	-	0.47	0.18
TiO_2	-	0.72	0.05
Loss on ignition	-	13.65	0.10

It was found possible to extract 90 per cent of the alumina from the kaolin and 84 per cent from the kyanite.

The process, as applied to these materials, is identical in principle to that described for the treatment of nepheline syenite; it is modified in procedure to allow for the lack of alkalies. The lack of alkali necessitates an increase in the quantity of limestone used and some changes in the balance and recycling of alkali solutions. Laboratory tests indicate that the process loss of alkalies would be small.

It has been suggested that the process might be applied for extraction of alumina from Georgia kaolin or

English china clays. Analysis of an average English clay shows a lower alumina content than the Georgia clay tested but also a higher alkali content. The latter would very probably be enough to more than offset the process loss in alkali. The following analysis has been reported as typical:

Analysis of English China Clay.

		Per cent
Silica	-	47.00
Alumina	-	37.72
Titania	-	0.15
Fe_2O_3	-	0.96
CaO	-	0.19
MgO	-	0.18
K_2O	-	1.57
Na_2O	-	0.23
Loss on ignition	-	12.37

As there are extensive supplies of coal and limestone within economical distance of the clay deposits, it is believed that the process might be of present interest in furnishing a source of alumina in England from domestic raw materials.

An estimate of production costs in the case of Georgia clay has been given in the appropriate section of this report.

FRA:PES.

REPORT ON GRADES AND TONNAGES OF NEPHELINE ROCK AND LIMESTONE, BANCROFT DISTRICT, ONTARIO,

by

N. H. C. Fraser.[⊕]

Introduction:

This report reviews the results to date of the diamond drilling carried out on the nepheline rocks and limestone of the above-mentioned district. A summary of grade and tonnage possibilities is presented which will serve as a basis for discussion and for coordination of the various phases of the project, especially Mr. Archibald's test work in Ottawa.

Diamond drilling was done in two sections of the Bancroft district, namely, the York River area and the Bancroft Nepheline area. Results for the York River work are almost complete at the present time. All analyses except those for three short drill holes recently completed are now available. Mr. Archibald has completed test work on core samples of the York River rock. From this work it appears that rock grading about 24 per cent Al_2O_3 may yield a satisfactory product by flotation. The drill results indicate that the tonnage of this grade and better which could possibly be obtained is about 14,000 tons per slope foot of depth.

All results are not yet available from work in the Bancroft Nepheline area but enough have been received to form a basis for discussion of this occurrence. Unfortunately it cannot be carried as far as with the York River

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⊕ Field Engineer for American Nepheline Corporation.

area. The results indicate that the best grade of rock which could be obtained is 26 per cent to 27 per cent Al_2O_3. The tonnage of rock of this grade is not definitely known but there is the possibility that 15,000 to 20,000 tons per foot of depth might be obtained. With regard to the possibility of improving the grade by flotation, it is pointed out that the Bancroft rock has a much larger carbonate and mafic content than the York River rock and hence, an initial grade of better than 24 per cent Al_2O_3 probably would be necessary to yield a satisfactory product by flotation.

Limestone possibilities were discussed fully in an earlier report (Jan. 5, 1942) and only a summary of them will be given in this report.

The possible tonnages and grades indicated by exploratory diamond drilling in the Nepheline and Limestone area are listed in the following table. It must be emphasized that the intervals between the drill holes are too great to assure continuity of the grades indicated and that detailed drilling is required to confirm these estimates.

York River Area

		Tons per Slope Ft.	
Block A.	30% Al_2O_3 or better		
	(1) Vicinity of D.D. Hole Yr-1	1,000	
	(2) In D.D. Hole Yr-9	500	1,500
	28% Al_2O_3 or better- D.D.H. Yr-1 & 2		3,000
	24% Al_2O_3 or better		
	(1) As for 28% +	3,000	
	(2) In D.D.H. Yr-5	3,500	
	(3) In D.D.H. Yr-1 & 9	2,500	
	(4) In D.D.H. Yr-9 & 10.	5,000	14,000
	21% Al_2O_3 Zones B & C		60,000
	19% Al_2O_3 Total		175,000
Block B.	Some samples of 24% grade and better but tonnage unknown.		

Bancroft Nepheline Area

			Tons per Slope Ft.
Davis Hill Area	$29\%\ Al_2O_3$ or better		
	If any, only small tonnages.		
	$26\%-28\%\ Al_2O_3$		
	(1) Davis Hill	3,300	
	(2) Davis-Cancrinite Hill	8,000	
	(3) Lily Robertson Hill	7,000	18,500
	$24\%\ Al_2O_3$ or better - Average of Davis Hill Area.		15,000,000 tons
Cooney Hill Area	$23\%-24\%\ Al_2O_3$ (Aver.Grade for Area, probably small tonnages of higher grade)		5,000,000 tons

Limestone

Bronson Station $83\%-84\%\ CaCO_3$ - 100,000

Deposit			
$91.5\%\ CaCO_3$	over	92.5'(width)	T nnages unknown but with these widths probably fairly large
$89.5\%\ CaCO_3$	"	197.0'(")	
$88.8\%\ CaCO_3$	"	145.0'(")	

Stoney Lake $90\%\ CaCO_3$ - Above Lake Level 500,000 tons

Deposit (Larger tonnage by mining below lake level with maximum of 3,000,000 tons)

Palaeozoic Limestones $95\%\ CaCO_3$ and better - Large tonnages probably could be obtained.

Geology

The main features of the geology of the nepheline rocks have been described in several earlier reports. A considerable amount of additional study has been given to the problems but no reasons found to change the main conclusions previously reached. With the additional work and later results, however, the possible importance of minor structures in the nepheline rocks has been disclosed which was not discussed before. There appears to be a relationship between better grade nepheline rock and fold structures. This appears to hold for both the Bancroft and York River areas.

In the York River area, nepheline rock of the highest grades occurs in the drag folded area near the Morrison quarries. Further north in Concession 15 better grade nepheline rock is found in a contorted area. In the Bancroft area, the best grade nepheline rock appears to have developed as on echelon lenses in a prominent drag fold on the Davis and Lily Robertson hills.

Why better-grade rock should be related to such structures is not clear but possibly pressure conditions may have controlled the development of a purer nepheline rock. The key to the problem may lie in the age of the structures. If the folds formed contemporaneously with the nepheline, low pressure zones or openings may have been developed in which nepheline crystallized most readily. If the folds are later than the nepheline, the development of the nepheline-rich rock may be due to recrystallization or solution activity controlled by the structures. The possibility that the folds are pre-nepheline in age has been considered. In this case the selectivity characteristic of replacements may have been involved or the structural weaknesses may have been the loci of more intense alterations.

If the higher grade nepheline rock is related to folded structures, then its continuity at depth probably will depend on the continuity of the structures. In the instances noted the fold structures are drag folds which might have only a limited extent. In view of this, exploration of the better-grade rock possibilities should be of detailed character and probably should be extended well beyond immediate requirements so that calculations could be made of what tonnage ultimately might be obtained.

York River Area:

Diamond drilling was carried out in two parts of the York River area. Most of the work was done in a block largely in Concession 13, but extending into Concessions 12 and 14. This will be referred to as Block A. It is 4200 feet in length and is bounded by D.D.H.'s Yr-10 and 11. Two drill holes were put down in Concession 15 about three-quarters of a mile north of Block A. The block explored by these drill holes will be referred to as Block B. It is 750 feet in length and is bounded by Diamond Drill Holes Yr-12 and 13.

Grades and Tonnages -

The thickness of the nepheline band in Block A is about 500 feet and in Block B, slightly narrower. With the lengths given above the tonnages per slope foot available in these blocks are of the order of 175,000 tons and 25,000 tons, respectively.

The approximate average composition of the rock in these blocks as determined from the composite samples of the drill cores is given in the following table:

		Block A	Block B
		(Per cent)	
Al_2O_3	-	19	17.5
SiO_2	-	41	36
Fe_2O_3	-	10	10
TiO_2	-	0.7	0.3
CaO	-	12	16
Na_2O	-	6	5
K_2O	-	3	2.5

It will be noted that the grade in alumina for the large tonnages is very low. Portions of the nepheline band, however, are of much higher grade.

By detailed study of the drill cores in Block A, it has been possible to subdivide the nepheline band into three members which have been called the lower, middle and upper members. In places, further subdivision of the upper member into zones was also possible. Compositional and textural differences are the basis for the divisions.

The lower member characteristically carries considerable biotite, feldspar and calcite. The middle member consists of coarse-textured aggregate of nepheline and amphibole. The upper member, generally medium to fine grained, has a very variable composition. The amount of dark mineral in the nepheline rock varies greatly and bands of limestone, paragneiss and nepheline pegmatite are interbedded.

In Block B, only two cross-sections of the nepheline band are available. They bear some similarity to the sections in Block A but direct correlations are impossible. The two sections in Block B differ rather greatly from each other and only tentative correlations between them can be made.

Block A:

The following table is presented to show the distribution of grades of rock in Block A according to the divisions outlined above:

			Average width	Average Al_2O_3
	Zone C	-	100'	21%
Upper Member	Zone B	-	110'	21%
	Zone A	-	65'	18.5%
Middle Member		-	100'	17%
Lower Member		-	110'	18%

A study of the assay plan on which are shown the

(Block A, cont'd) -

individual sample results will reveal that in the lower and middle members there is little possibility of getting rock much above the average grades since analyses are all uniformly low. In the two uppermost zones of the Upper Member, however, the average grade is about 21 per cent Al_2O_3. A tonnage of the order of 60,000 tons per slope foot of this grade is available.

In the following paragraphs a discussion will be given of the tonnage possibilities of various other grades from the best down:

<u>30% Al_2O_3 or better:</u>

(1) In the upper part of Diamond Drill Hole Yr-1, 55 feet of rock averaging better than 30 per cent Al_2O_3 was cut. This rock extends southward to Yr-14 in which 17 feet of rock which will probably have similar grade was intersected. The extent of the rock north of Yr-1 is not definitely known but probably it extends as a narrowing zone about 200 feet north where it is cut off by pegmatite. With these dimensions a tonnage of about 1000 tons per slope foot would be available.

(2) In D.D.H. Yr-9, 53 feet of 30 per cent rock was cut. This rock lenses out to the north within 200 feet since it does not appear in Yr-16. The southward extent is not known but probably it will lens out within a short distance in this direction also. Assuming a length of 400 feet for this high-grade rock, a tonnage of about 500 tons per slope foot would be available.

<u>28% Al_2O_3 or better:</u>

At a grade of 28 per cent, a greater width of

(Block A, cont'd) -

rock can be taken in Yr-1 than for the calculation above. The rock in the upper part of Yr-2 can be included also. With these additions a tonnage about double that of the 30 per cent grade, or 3,000 tons per slope foot, would be available.

24% Al_2O_3 or better:

At a grade of 24 per cent an appreciably greater tonnage could be obtained. To the tonnage arrived at above could be added 3,500 tons per slope foot grading about 26 per cent Al_2O_3 lying in the area north of the Morrison Quarries, and cut in D.D.H. Yr-5.

Between D.D.H.'s Yr-1 and 9 in Zone A there is probably a zone which will average a little better than 24 per cent. If this zone is continuous between these drill holes, it could yield about 2,500 tons per slope foot. A second possibility which could yield about double this tonnage, or 5,000 tons per slope foot, is suggested by samples better than 24 per cent in the upper parts of Yr-9 and 10. These samples appear to lie in the same stratigraphic horizon but are widely separated. There is the possibility, however, that the indicated grade might persist between the drill holes.

The total tonnage per slope foot of 24 per cent rock and better which could possibly be obtained is, therefore, about 14,000 tons.

Block B:

In the upper part of D.D.H. Yr-12 there are several samples grading better than 24 per cent. The extent of this rock, however, is unknown and it is difficult to

(Block B, cont'd) -

make any sort of estimate of what tonnage might be available. The better-grade rock lies in a drag folded area which extends some distance south of the drill hole.

The best sample in Yr-13 gave 28.5 per cent Al_2O_3 over 28 feet. This sample might correlate with a 24-foot sample in Yr-12 at 26 per cent. There is thus the possibility of a better-grade zone extending between these holes.

Bancroft Nepheline Area:

Most of the diamond drilling on the Bancroft Nepheline locality was carried out in two places, namely, the Davis Hill area and the Cooney Hill area. Several drill holes were put in by Alco elsewhere but no results are available from these.

The ground which has been called the Davis Hill area lies in Lots 25 and 26, Concession 13. It is made up of three large hills, the Davis, Lily Robertson and Cancrinite. One large hill in the north part of Lot 27 constitutes the Cooney Hill area. Field work was concentrated on these areas since from preliminary examination they appeared to contain the largest quantities of the best rock.

Analyses are available from a number of surface samples taken in various places in the Bancroft Nepheline area. Most of these show grades of 29 per cent Al_2O_3 or better. The results of the diamond drilling are disappointing in that they show no grades equal to this, although the drill holes lie beneath surface material which samples showed to be very high grade. Before outlining the grade and tonnage possibilities as indicated by the drilling, it may be well to discuss the surface samples.

One reason that the surface samples show higher grade than the drill core samples is that they are taken over only short widths, and hence, may represent high-grade bands. The drill core samples are taken over fairly large widths and thus give the average compositions of zones in the rock rather than individual bands. Another reason is that surface samples may contain more alumina relatively due to the removal of such minerals as carbonates by weathering or to the deposition of alumina on weathering of silicates. For the above reasons surface samples may not be reliable.

On the data available, however, it cannot be stated definitely that there are no patches of rock grading 29 per cent Al_2O_3 or better but the drill results indicate that if they do exist they are of limited size.

Grades and Tonnages

Davis Hill Area:

The average grade of rock in the Davis Hill area is approximately 24 per cent Al_2O_3. A tonnage of the order of 15,000,000 tons down to valley level is available.

Individual samples, for the most part, vary but 2 or 3 per cent from the average and for this reason no large tonnage of much better than average grade can be calculated. Several sections, however, averaging between 26 and 28 per cent Al_2O_3 were cut in the drill holes. These are shown on the accompanying assay plan and their possible relationships indicated. The writer wishes to emphasize that these better-grade zones as shown are largely an interpretation. Postulating their existence, however, the tonnages available in them would be as follows:

		Tons/ft.
Zone in middle of Davis Hill ----	700' long x 60' wide --	3,500
Zone in Davis and Cancrinite Hills --	1000' " x 100' " --	8,000
Zones in Lily Robertson Hill -----	600' " x 100' " --	5,000
	400' " x 36' " --	1,200
	400' " x 24' " --	800
	Total --	18,500 tons per foot.

Cooney Hill Area:

One drill hole, Co-1, was drilled through the Cooney Hill to the lower contact. The average grade of rock cut is 23.01 per cent Al_2O_3. The highest results obtained are 25.68 per cent Al_2O_3 and 25.27 per cent Al_2O_3 over widths of 30 feet and 22 feet respectively.

One drill hole, Al-2, was put in at the west end of the Cooney Hill by Alco. This hole cut 88 feet running 28.18 per cent followed by 25 feet running 25.5 per cent and 75 feet running 26.86 per cent. Detailed structural data are not available at this location but the high-grade rock may form a lenticular body in a sharp drag fold as shown on the assay plan.

Insufficient data are available to draw too definite conclusions with regard to the Cooney Hill area. In view of the general similarity of this and the Davis Hill area the average grade of 23 to 24 per cent Al_2O_3 indicated by D.D.H. Co-1 appears reasonable. It seems likely also that elsewhere in the Cooney Hill better-grade rock similar to that in Al-2 could be found, but the tonnages of it probably would not be great.

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Limestone Possibilities:

Bancroft District -

Two diamond drill holes were put in a limestone deposit lying 2 miles south of the Davis Hill area. The deposit is located on the railway about one-half mile from Bronson Station.

The tonnage available in this deposit is estimated at about 100,000 tons per foot of depth. The average grade of this tonnage, however, may be only about 83 to 84 per cent $CaCO_3$. High-grade sections occur within the deposit. In D.D.H. Ls-1, a section 92.5 feet in length gave 91.5 per cent $CaCO_3$ and another 197 feet in length, 89.5 per cent. In D.D.H. Ls-2, the best section gave 88.8 per cent $CaCO_3$ over 145 feet. The extent of these better-grade zones is not known and hence the tonnage available cannot be calculated. With reasonable extent, however, and the indicated widths it seems likely that fairly large tonnages could be obtained.

Two small deposits of relatively pure limestone lie a short distance east of Bancroft. Mr. Archibald obtained limestone from one of these for his test work in Ottawa.

Lakefield District -

A surface examination was made of a limestone deposit occurring on the north shore of Stoney Lake. The tonnage above lake level in this deposit was estimated at about 500,000 tons. By working below lake level the deposit probably could yield about 3,000,000 tons. This larger tonnage, however, would depend on the feasibility of mining below lake level and on the size of pillars which would have to be left at the lake shore. The grade of the deposit appears to be about 90 per cent $CaCO_3$.

Palaeozoic Limestones -

Palaeozoic limestones occurring in Peterborough, Hastings and Victoria counties are exceptionally pure, many of them ranging in $CaCO_3$ content from 95 per cent upward. These limestones would be important if a plant at Lakefield were contemplated. Otherwise they are only of lesser importance since at their closest point they lie about 40 miles from the nepheline areas.

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(February, 1942.)
(N.H.C. Fraser.)

BIBLIOGRAPHY OF RECORDS.

Our record of investigation includes the following:

A. Summary Reports:

Part 1 - with accompanying summary of abstract references; March 30, 1939.
Part 2 - July 21, 1939.
Part 3 - September 12, 1939.
Part 4 - November 30, 1939.
Part 5 - with accompanying Abstract Summary of Patent Literature; Feb. 14, 1940.
Part 6 - December 31, 1940.
Part 7 - The present report.

B. Progress Reports:

A series of 25 progress reports summarizing and interpreting the results of test work at intervals throughout the period from September 6, 1940, to January 31, 1942.

C. Log Books:

The original record of recorded data and observations.

D. Drilling Record and Other Geological Studies.

Included are reports by M. L. Keith, N. H. C. Fraser, D. R. Derry, S. V. Burr and W. K. Gummer, with accompanying maps by Keith, Fraser and Gummer.

E. Aerial photographs of the areas concerned, furnished by the Geological Survey of Canada and the Ontario Department of Lands and Forests.

F. Drawings and a list of equipment for a proposed 100-ton plant, with estimates and proposals from manufacturers.

G. Reports by C. M. Nicholson on the extraction of alumina from kaolin and kyanite.

Index to Diagrams, Illustrations and Maps:

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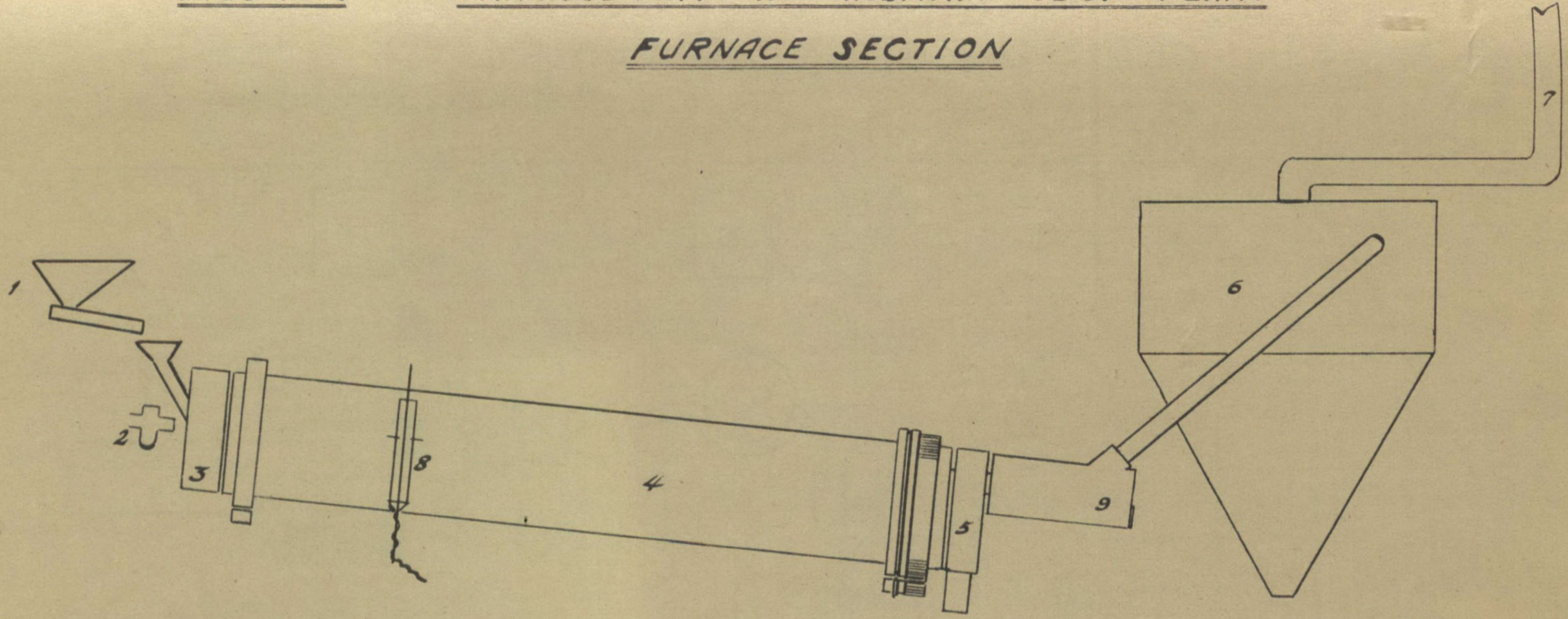
FIGURE 1 ARRANGEMENT of ALUMINA TEST PLANT

FURNACE SECTION



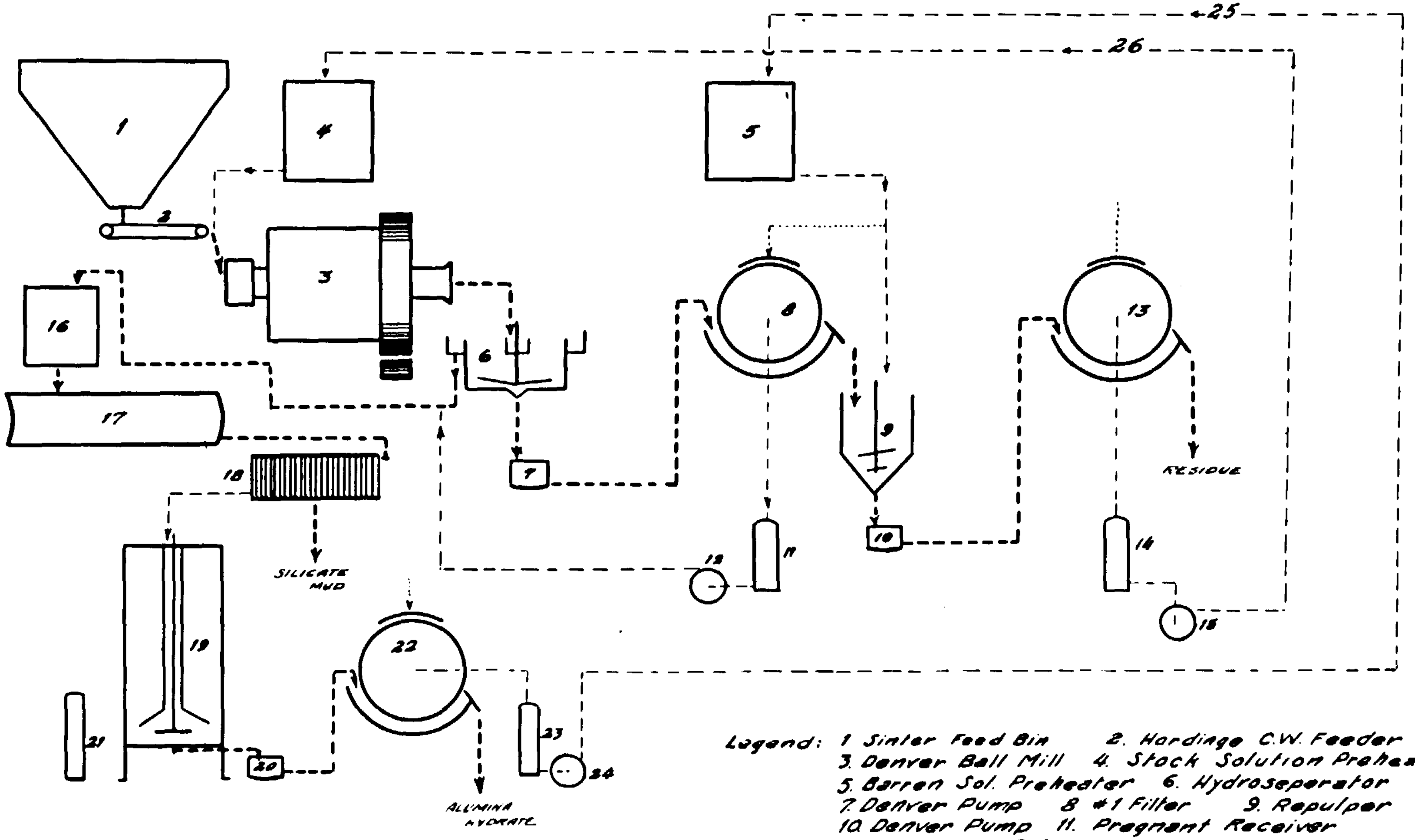
Legend: 1. Jeffrey Vibrating Feeder 2. Anthony Nebulyte Burner 3/4". 3
3. Combustion Block 4. Kiln, 16" to 12" I.D. × 12 Ft.
5. Discharge and Exit Flue Block 6. Dust Collector, (Cyclone)
7. Stack 8. Thermocouple with Slide Wire Take-off.
9. Settling Flue.

Ottawa, Feb. 10, 1942.

F R Archibald

FIGURE 2 ARRANGEMENT of ALUMINA TEST PLANT

LEACHING SECTION



Legend: 1 Sinter Feed Bin 2. Hardinge C.W. Feeder
3. Denver Ball Mill 4. Stock Solution Preheater
5. Barren Sol. Preheater 6. Hydroseperator
7. Denver Pump 8 #1 Filter 9. Repulper
10. Denver Pump 11. Pregnant Receiver
12. Pregnant Solution Pump 13. #2 Filter
14. Receiver 15. Pump 16. Pregnant Sol'n Preheater. 17. Pressure Tank 18. Filter Press 19. Seeding Tank 20. Denver Pump
21. CO_2 Cylinder 22. Hydrate Filter
23. Barren Solution Receiver 24. Sol'n Pump
25. Barren Solution Storage, 1000 gals.
26. Stock Solution Storage, 1000 gals.

Pulps & Solids - - - - -
Solutions — — — —
Wash ....

Ottawa Feb. 11, 1942
F.R. Archibald

FIGURE 3

ALUMINA RECOVERY PLANT

FLOW SHEET DIAGRAM for PLANT to TREAT 100 TONS ROCK PER DAY

SCALE: NONE

DRAWN BY: F.R. ARCHIBALD

OTTAWA: MAR 5, 1943

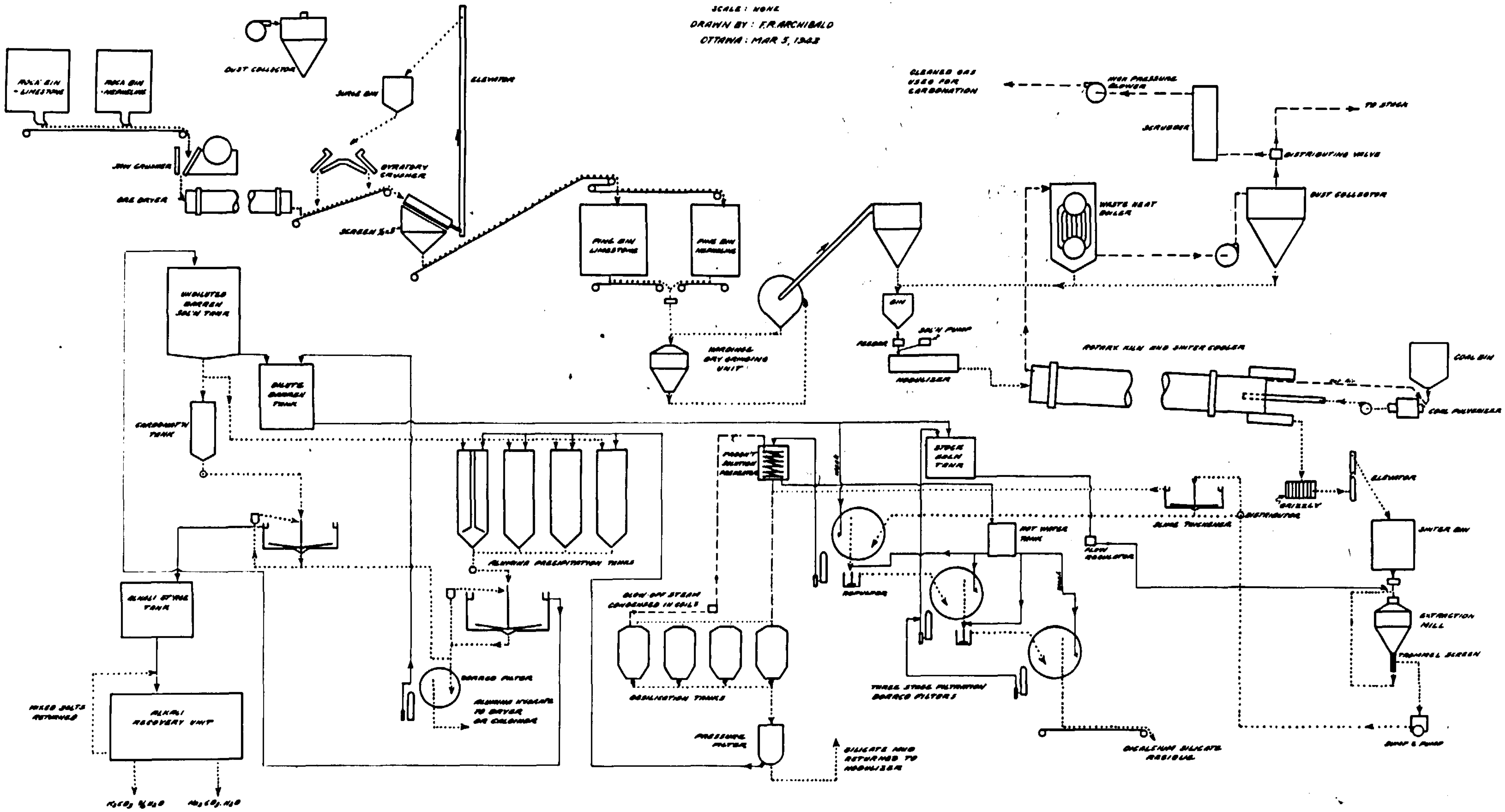
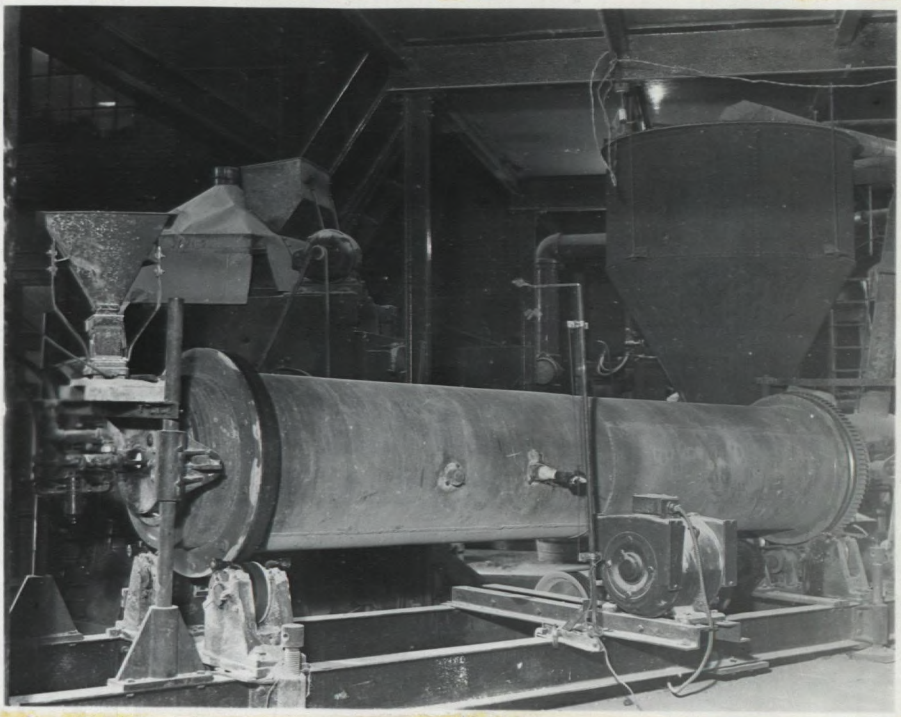
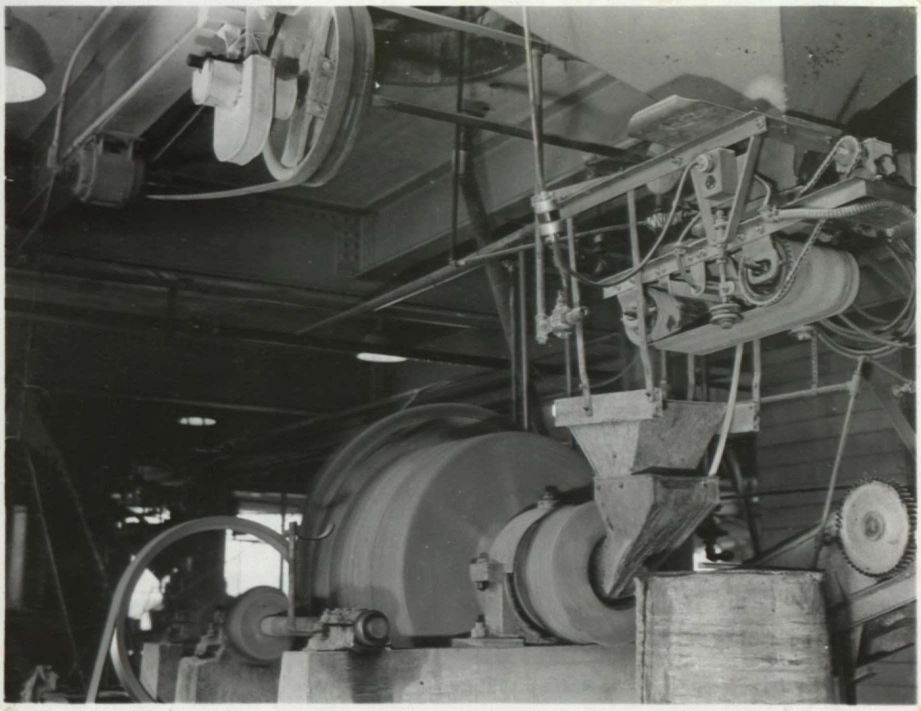


Illustration 1.



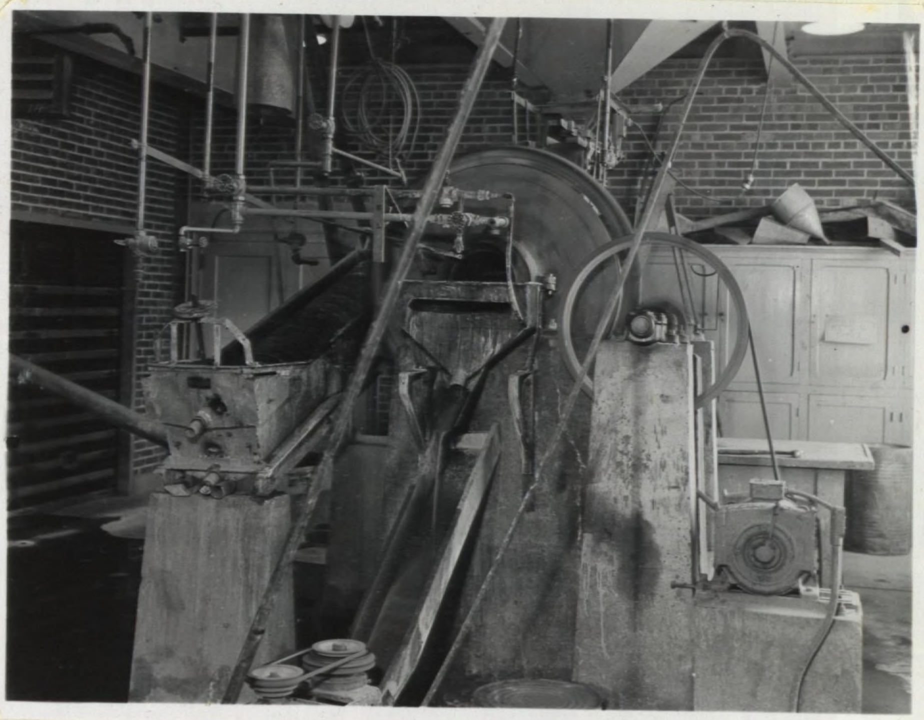
Rotary Kiln, used in sintering operation. (Refer to Figure 1).

Illustration 2.



Denver Ball Mill, used in grinding sinter with leaching solution, feed end.

Illustration 3.

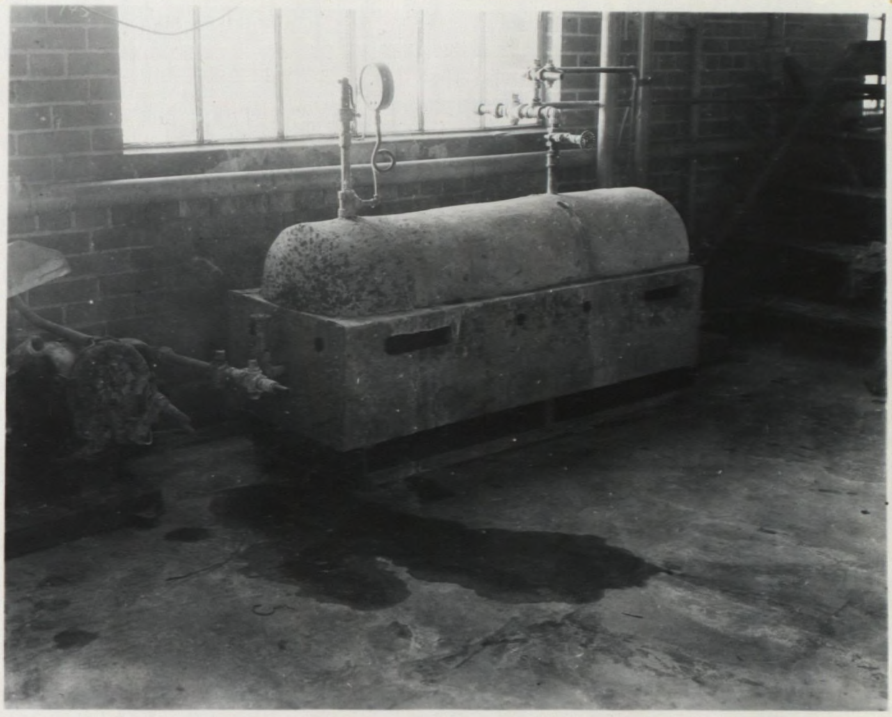


DENVER BALL MILL, DISCHARGE END.

Illustration 4.

Oliver filter, filtering aluminate
solution from dicalcium silicate residue.

Illustration 5.



Pressure vessel, used in desilication step.

Illustration 6.

Oliver filter, showing discharge of alumina hydrate product. Alumina precipitation tanks shown on right.

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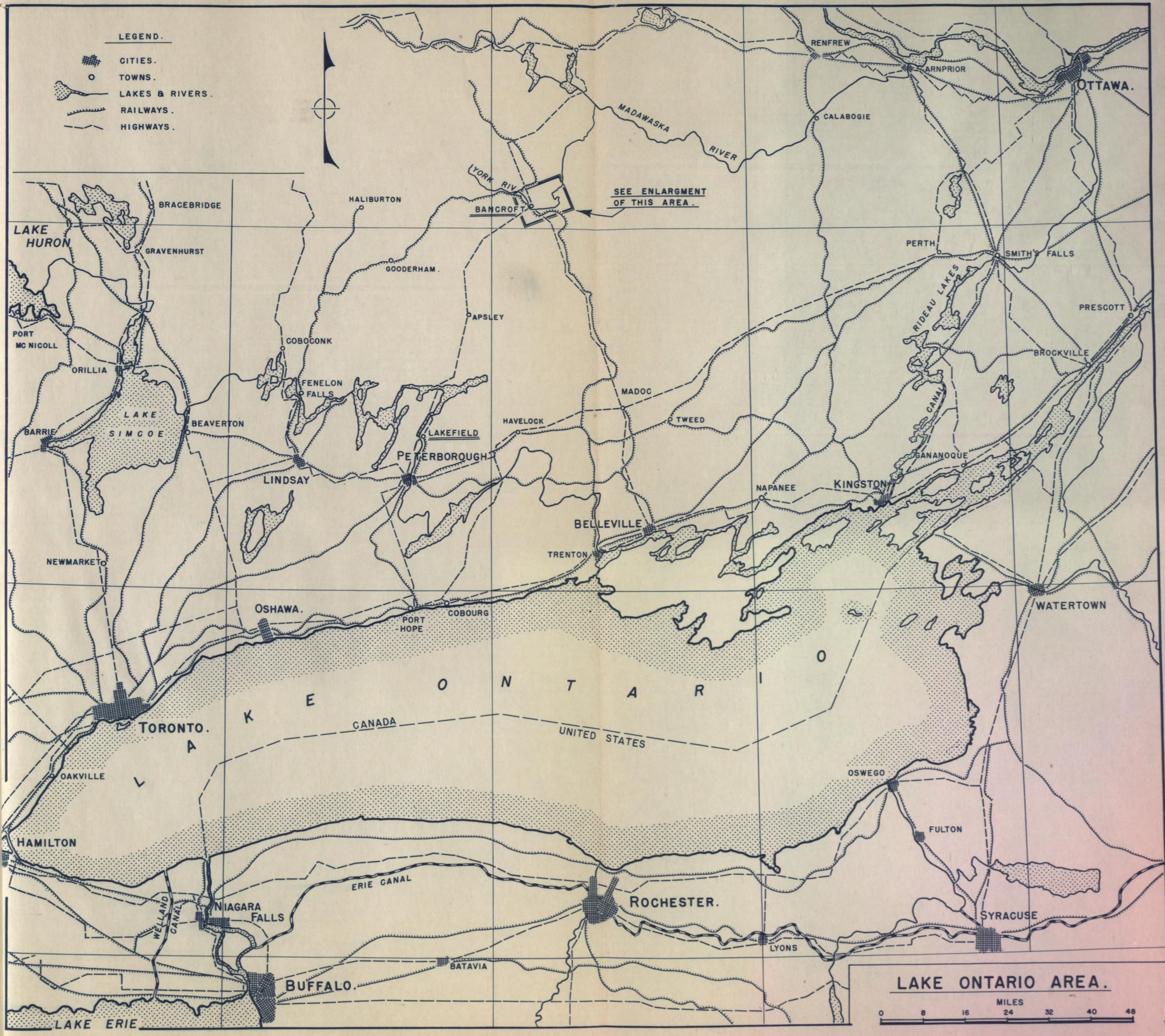
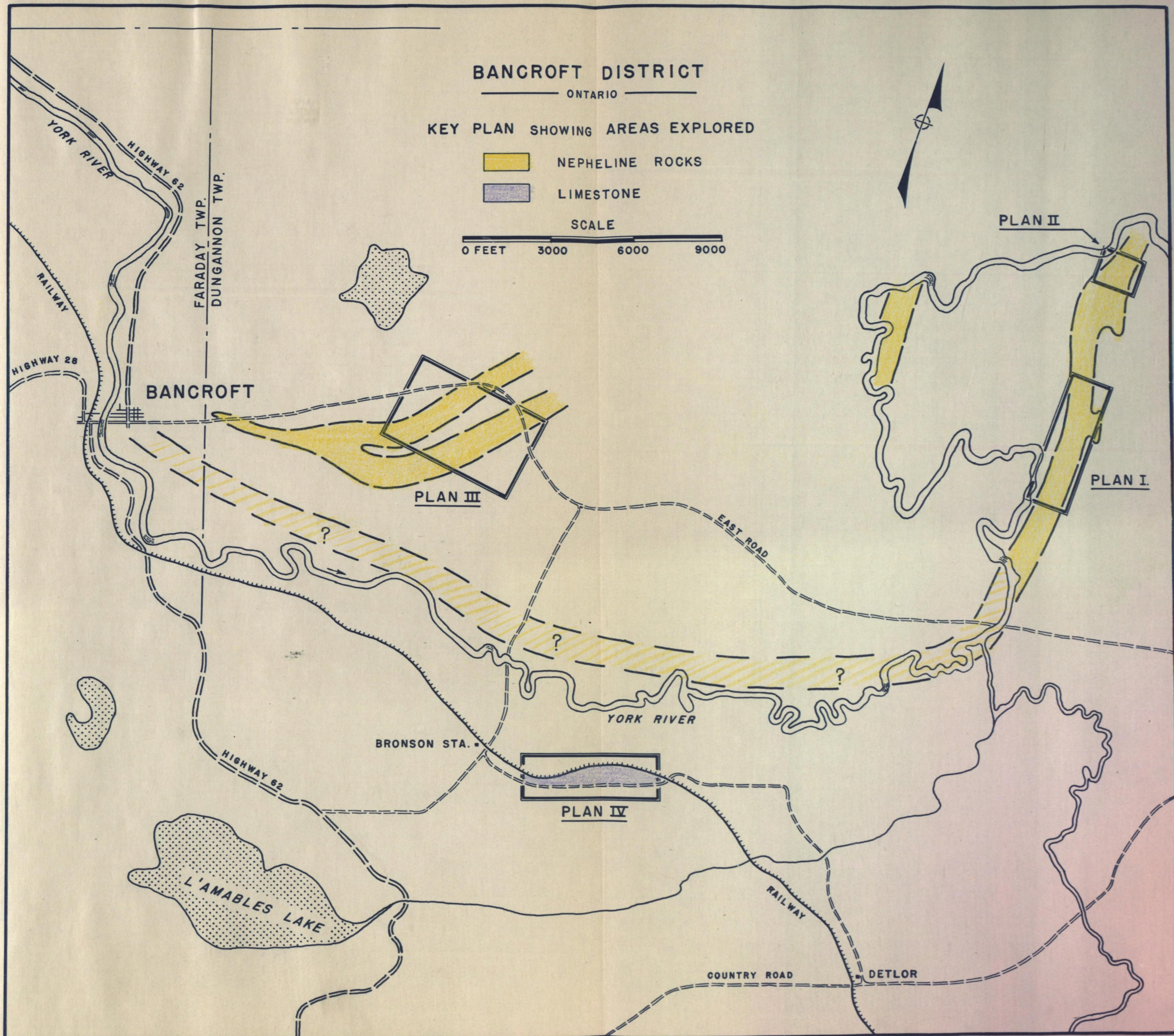
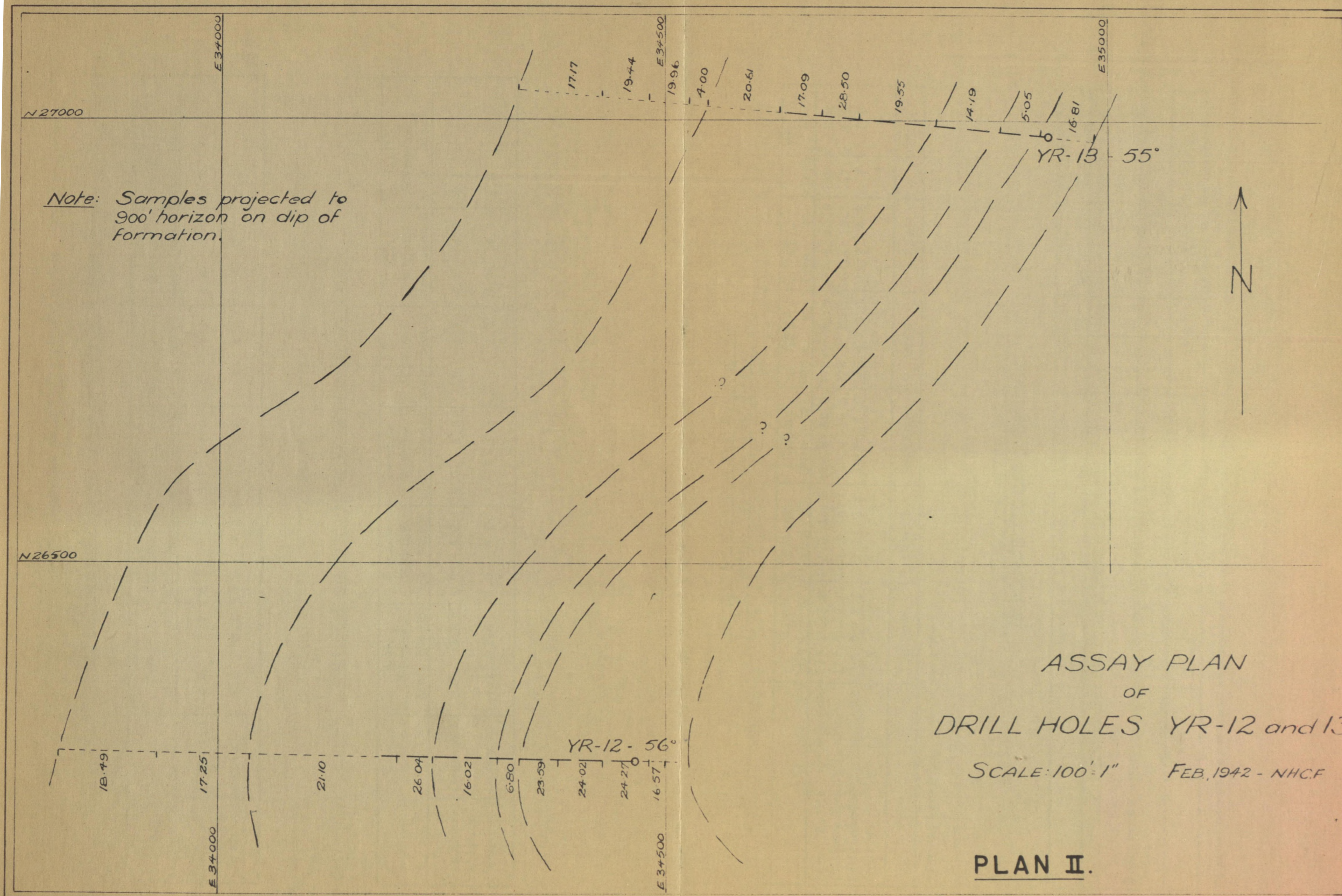
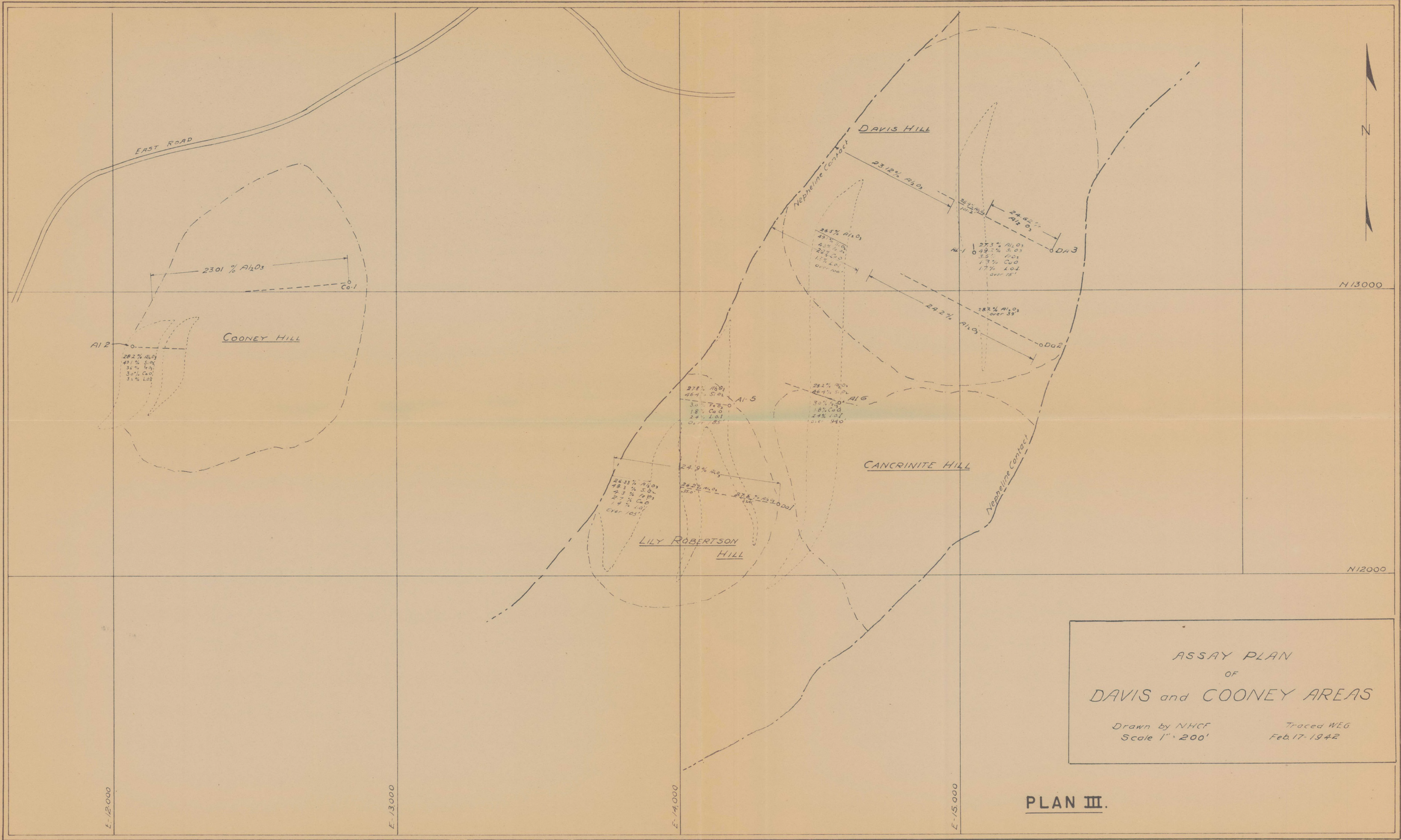

LEGEND.
CITIES.
TOWNS.
LAKES & RIVERS.
RAILWAYS.
HIGHWAYS.
RENFREW
ARNPRIOR
OTTAWA.
MADAWASKA RIVER
CALABOGIE
YORK RIV
BANCROFT
SEE ENLARGMENT OF THIS AREA.
HALIBURTON
BRACEBRIDGE
LAKE HURON
GRAVENHURST
GOODERHAM.
PERTH
SMITH'S FALLS
RIDEAU LAKES
PRESCOTT
APSLEY
PORT MC NICOLL
COBOCONK
BROCKVILLE
ORILLIA
FENELON FALLS
MADOC
CANAL
LAKE SIMCOE
BEAVERTON
HAVELOCK
TWEED
BARRIE
LAKEFIELD
PETERBOROUGH
GANANOQUE
LINDSAY
NAPANEE
KINGSTON
BELLEVILLE
TRENTON
NEWMARKET
WATERTOWN
OSHAWA.
PORT -HOPE
COBOURG
LAKE ONTARIO
TORONTO.
CANADA
UNITED STATES
OAKVILLE
OSWEGO
HAMILTON
FULTON
ERIE CANAL
WELLAND CANAL
NIAGARA FALLS
ROCHESTER.
SYRACUSE
LYONS
BATAVIA
BUFFALO.
LAKE ERIE
LAKE ONTARIO AREA.
MILES
0 8 16 24 32 40 48


BANCROFT DISTRICT
ONTARIO
KEY PLAN SHOWING AREAS EXPLORED
NEPHELINE ROCKS
LIMESTONE
SCALE
0 FEET 3000 6000 9000
PLAN II
PLAN I.
PLAN III
PLAN IV
BANCROFT
YORK RIVER
HIGHWAY 62
HIGHWAY 28
RAILWAY
FARADAY TWP.
DUNGANNON TWP.
EAST ROAD
BRONSON STA.
L'AMABLES LAKE
COUNTRY ROAD
DETLOR

Limestone
LOWER MEMBER
MIDDLE MEMBER
ZONE-A
AND
ZONE-B
ZONE C ?
Zone-A
Zone-B
Zone-C
UPPER MEMBER
Probably continues
Limestone
LEGEND
Nepheline rock
Limestone
Paragneiss
Pegmatite
PLAN I.
NOTE- Samples projected to 1,000 ft. horizon on dip of formation
33,500 E
34,000 E
18000N
18500N
19000N
19500N
22,000 N
ASSAY PLAN
OF
DRILL CORE SAMPLES
YORK RIVER NEPHELINE AREA
Drawn by N.H.C.F-L.M
Scale 1" = 100'
Traced by W.E.G.
Feb. 10 - 1942

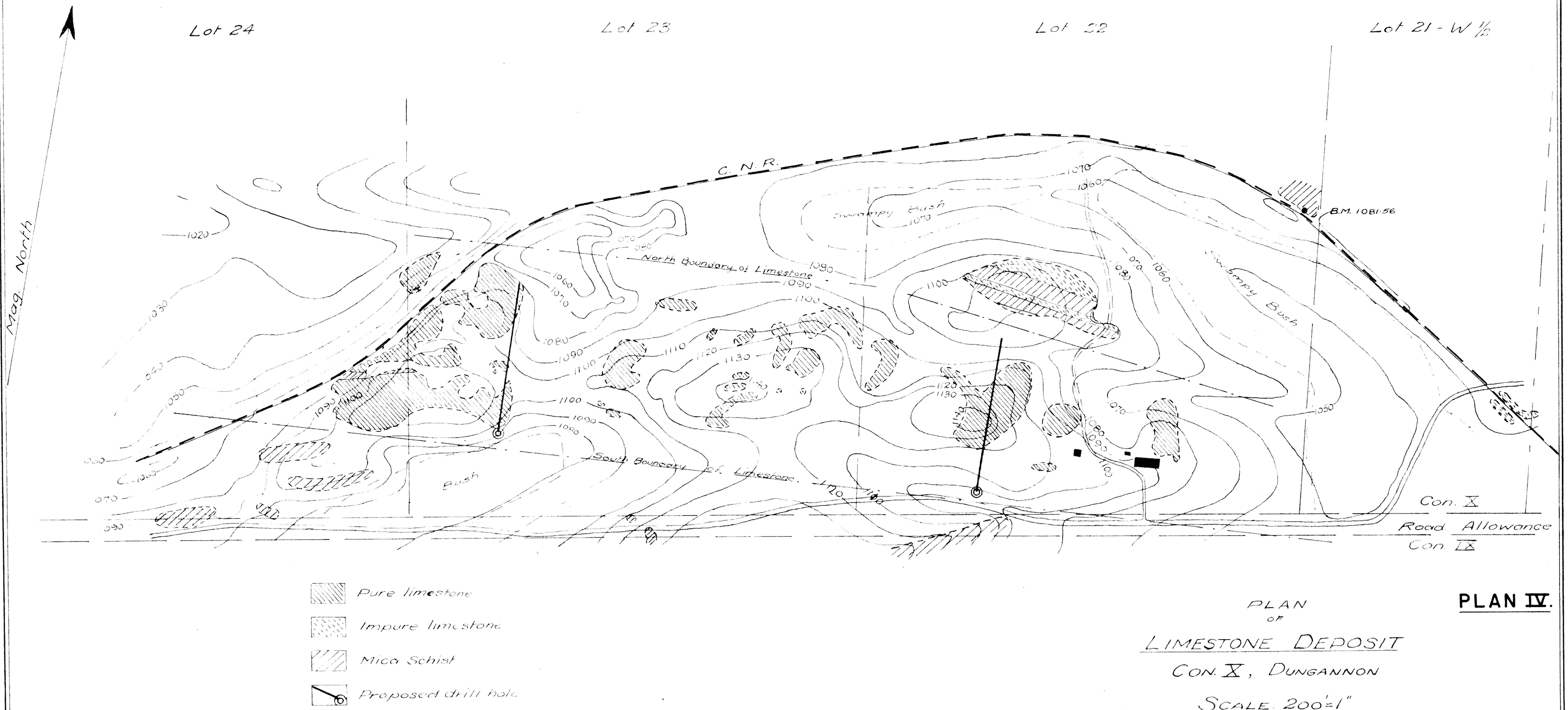


E 34000
E 34500
E 35000
N 27000
N 26500
17.17
19.44
19.96
4.00
20.61
17.09
28.50
19.55
14.19
5.05
16.81
YR-13 - 55°
Note: Samples projected to 900' horizon on dip of formation.
N
?
?
?
YR-12 - 56°
18.49
17.25
21.10
26.04
16.02
6.80
23.59
24.02
24.27
16.57
ASSAY PLAN
OF
DRILL HOLES YR-12 and 13
SCALE: 100' = 1"
FEB. 1942 - NHCF
PLAN II.



EAST ROAD
23.01 % Al2O3
Co-1
COONEY HILL
Al 2
28.2 % Al2O3
43.1 % SiO2
3.6 % FeO3
3.0 % CaO
3.2 % L.O.I
DAVIS HILL
Nepheline Contact
23.12% Al2O3
26.9% Al2O3
101.2'
24.62 % Al2O3
DA 3
26.5% Al2O3
49.1% SiO2
4.3% FeO3
2.2% CaO
1.5% L.O.I
over 100'
Al-1
27.3 % Al2O3
49.2 % SiO3
3.5 % FeO3
1.3 % CaO
1.7 % L.O.I.
over 75'
24.2 % Al2O3
28.2 % Al2O3
over 39'
Da 2
N
N 13000
27.8 % Al2O3
46.4 % SiO2
Al-5
3.0 % FeO3
1.8 % CaO
2.4 % L.O.I
Over 185'
28.2 % Al2O3
46.4 % SiO2
Al 6
3.0 % FeO3
1.8 % CaO
2.4 % L.O.I
over 940'
24.9 % Al2O3
26.33 % Al2O3
48.3 % SiO2
4.3 % FeO3
2.7 % CaO
1.4 % L.O.I
Over 105'
26.2 % Al2O3
35.0'
27.6 % Al2O3
23.0'
Da 1
CANCRINITE HILL
Nepheline Contact
LILY ROBERTSON HILL
N 12000
ASSAY PLAN
OF
DAVIS and COONEY AREAS
Drawn by NHCF
Scale 1" = 200'
Traced WEG
Feb. 17-1942
E. 12,000
E. 13,000
E. 14,000
E. 15,000

PLAN III.



PLAN IV.

PLAN OF LIMESTONE DEPOSIT

CON. X, DUNGANNON

SCALE 200'=1"

Oct. 21, 1941 N.H.C.F.