SYNCRUDE KAOLIN RECOVERY PROJECT

1.0 SUMMARY

A program has been conducted to produce bulk samples of dried clay, to be shipped to ECC in Georgia for calcination testing. In the course of the pilot plant program Syncrude's Mature Fine Tails were upgraded by dispersing bitumen, clay and silt. The grade of clay, as measured by silica and alumina content, improved from 69.6% SiO_2/ 20.7% Al_2O_3 in MFT to 56.2% SiO_2/31.0% Al_2O_3 . A total of 670 kg of dried clay was shipped to ECC.

A commercial plant has been scoped out based on bench scale test work, pilot plant experience and data provided by equipment vendors who are experienced in processing kaolin. The capital cost for a plant producing 22,000 tonnes per year of calcined clay is estimated to be $32 million, including owner's project costs. The operating cost per tonne of calcined clay is estimated at $167 per tonne. The net present value over twenty years of production at 22,000 tonnes per year is $156 million before inflation and taxes.

2.0 INTRODUCTION

Syncrude Canada Ltd has initiated a project to recover a kaolin rich slurry from oil sands tailings. The recovered product has been identified as a potential pozzolanic supplement in specialty cements. This report describes the laboratory and pilot plant work, which produced a bulk sample of slurry. The slurry sample was sent to ECC in Georgia for calcining and product evaluation.

The report also contains a description and cost estimate of a commercial plant to generate the initial annual quantity of product required by ECC.

3.0 SCOPE OF WORK

Tynebridge Technologies Limited was contracted by Syncrude to achieve the following objectives:

- Identify the clays present in Plant 6 tailings and mature fine tails
- Investigate flocculation of samples
- Bench test froth flotation
- Bench test dewatering methods (filtration)
- Provide nominal 1,000 kg of dried clay by the end of July

Tynebridge's scope items included:

- Technical direction for Birtley Coal and Minerals
- Determine the best selection of feedstock
- Develop a workable flowsheet using the selected feedstock
- Prepare a class 10 level cost estimate for the selected flowsheet
- Identify any areas requiring work outside the identified scope

- Identify scale up factors as appropriate
- Oversee the technical operation of the pilot plant as required

4.0 BENCH SCALE TESTS

The original plan was to test two clay sources (Mature Fine Tails and Plant 6 Heavy Phase) by conducting flocculation, flotation and filtration tests. Prior work by Syncrude Research indicated that Mature Fine Tails would be the most suitable source of kaolinite, and that upgrading could be achieved by the use of sodium silicate as a dispersant.

The bench scale tests were therefore scaled back to a demonstration of dispersion with and without froth flotation. Table 1 contains comparative analyses of standard kaolin, raw MFT and bench scale mid-clays with and without vigorous agitation by froth flotation. Note that kaolin is usually reported with 15% Loss On Ignition. The assay in Table is on an LOI-free basis to be comparable to the mineral ash analyses at Birtley.

Sample		SiO2	Al2O3	TiO2	Fe2O3	CaO	MgO	Na2O	K2O	P2O5	SO3
Standard Kaolin		53.50	44.00	0.47	0.85	0.18	0.08	0.14	0.06	0.29	0.32
Syncrude MFT		69.63	20.73	1.02	3.60	0.41	1.01	0.59	2.45	0.14	0.30
Bench Gravity Sep		67.04	22.51	1.12	3.75	0.38	1.08	0.85	2.63	0.13	0.27
Bench Flotation Sep		57.11	30.57	1.12	4.35	0.38	1.36	1.23	3.16	0.13	0.20

Table 1

The flotation test did not provide a means of extracting bitumen quickly, but it did show the positive benefits of vigorous agitation followed by a settling period.

5.0 PILOT PLANT TESTS

Two batches were prepared through Birtley's pilot plant.

The results of Batch #1 are shown in Table 2:

Syncrude Kaolin Recovery Project

Comparison of Analyses											
Sample		**SiO2**	**Al2O3**	**TiO2**	**Fe2O3**	**CaO**	**MgO**	**Na2O**	**K2O**	**P2O5**	**SO3**
Standard Kaolin		53.50	44.00	0.47	0.85	0.18	0.08	0.14	0.06	0.29	0.32
Syncrude MFT		69.63	20.73	1.02	3.60	0.41	1.01	0.59	2.45	0.14	0.30
Bench Gravity Sep		67.04	22.51	1.12	3.75	0.38	1.08	0.85	2.63	0.13	0.27
Bench Flotation Sep		57.11	30.57	1.12	4.35	0.38	1.36	1.23	3.16	0.13	0.20
Pilot		Cumulative Analyses									
Minus 6"		60.58	28.08	1.20	4.35	0.39	1.29	1.12	3.06	0.15	0.17
Minus 18"		61.54	27.13	1.19	4.21	0.39	1.25	1.05	2.99	0.16	0.19
Minus 30"		62.37	26.33	1.18	4.11	0.39	1.22	1.01	2.95	0.14	0.21
Minus 42"		63.32	25.49	1.16	4.01	0.40	1.12	0.96	2.89	0.14	0.22
Recovery based on	Al2O3	Analysis of residue based on recovery									
	Weight	SiO2	Al2O3	TiO2	Fe2O3	CaO	MgO	Na2O	K2O	P2O5	SO3
Syncrude MFT	1										
Bench Gravity Sep	92.1%	99.79	-	-0.14	1.85	0.76	0.19	-2.44	0.35	0.26	0.65
Bench Flotation Sep	67.8%	96.01	-	0.81	2.02	0.47	0.27	-0.76	0.95	0.16	0.51
Pilot	Based on weight percent of MFT and mid-clay identical										
Minus 6"	10.0%	70.64	19.91	1.00	3.52	0.41	0.98	0.53	2.38	0.14	0.31
Minus 18"	30.0%	73.10	17.99	0.95	3.34	0.42	0.91	0.39	2.22	0.13	0.35
Minus 30"	50.0%	76.89	15.13	0.86	3.09	0.43	0.80	0.17	1.95	0.14	0.39
Minus 42"	70.0%	84.37	9.62	0.70	2.64	0.44	0.76	-0.27	1.42	0.13	0.48

Table 2

Table 2 shows a gradation of alumina and silica with depth. The mineral ash analysis of the dried product is shown in Table 3:

MINERAL ANALYSIS OF ASH												
LAB NO:	SAMPLE ID:	SiO_2	Al_2O_3	TiO_2	Fe_20_3	CaO	MgO	Na_2O	K_20	P_20_5	SO_3	Undet.
84155	DRIED PRODUCT	62.82	25.93	1.18	4.18	0.45	1.19	0.96	2.87	0.13	0.30	0.01

Table 3

The analysis is consistent with the sample of clay slurry shown in Table 2. Because the alumina of the dried batch was lower than the target of 30%, the remaining clay was allowed to settle for five more days before sampling and analysis, as shown in Table 4:

MINERAL ANALYSIS OF ASH												
LAB NO:	SAMPLE ID:	SiO_2	Al_2O_3	TiO_2	Fe_20_3	CaO	MgO	Na_2O	K_20	P_20_5	SO_3	Undet.
84155	RESAMPLE 30"	64.19	24.77	1.20	3.97	0.45	1.16	0.90	2.79	0.16	0.27	-0.14
84155	SAMPLE @36"	65.58	23.70	1.10	3.83	0.42	1.13	0.86	2.78	0.15	0.27	-0.18

Table 4

The resultant alumina content did not increase with time. The sample was placed into barrels for shipment back to Syncrude. This indicates that the initial mixing and settling is the crucial period for separating silt from clay.

The silt from Batch #1 was also analysed, with the results in Table 5:

MINERAL ANALYSIS OF ASH												
LAB NO:	SAMPLE ID:	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
84155	BOTTOM SILT	90.33	5.84	0.64	1.13	0.21	0.50	0.18	1.45	0.03	0.10	0.41

Table 5

Batch #2 was run slightly differently, to maximize recovery and improve alumina content based on experience from Batch #1. Sodium silicate was added at the rate of 0.3% to help increase dispersion. A perforated air hose was set in the bottom of the tank. Air was run through this while filling the tank and for the first three days of settling. The tanker trailer was emptied, but this only half filled the tank. The mid clays left over from Batch #1 were added to increase level and to increase kaolinite recovery. Finally, the tank was topped off with fresh water. The mid clay sample from Batch #2 has an improved analysis (Table 6), with almost 31% alumina.

MINERAL ANALYSIS OF ASH												
LAB NO:	SAMPLE ID:	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
84180	MIDCLAY SAMPLE	57.27	30.90	1.17	4.10	0.41	1.32	1.63	3.07	0.09	0.10	0.06

Table 6

The mid clay was pumped to the drying pad. It was dried to approximately 4% surface moisture, crushed and placed into lined barrels. The crushed dried clay was weighed at 670 kg. Its analysis in Table 7 was consistent with the mid clay:

MINERAL ANALYSIS OF ASH												
LAB NO:	SAMPLE ID:	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	Undet.
84180	MIDCLAY SAMPLE	56.21	30.99	1.20	4.40	0.36	1.46	1.93	3.05	0.33	0.12	0.05

Table 7

6.0 FULL SCALE PLANT

6.1 Design Basis

The initial commercial plant has been sized to produce 22,000 tonnes of calcine per year. The design basis is contained in Table 8.

Nominal production rate	22,000	t/y calcine	4.40	t/h
Water of hydration before calcine		15%		
Dry kaolin rate	25,882	t/y	5.18	t/h
Surface moisture		1%		
Feed to calciner	26,144	t/y	5.23	t/h
Percent solids of mid clays		17.73%		
Flow rate of mid clay slurry	124,082	t/y	24.82	t/h
Specific gravity of mid clay slurry		1.124		
Volumetric flow of mid clay	110,384	m^3/y	22.08	m^3/h
Volumetric flow of MFT feed	135,475	m^3/y	27.10	m^3/h
Specific gravity of MFT		1.235		
Flow rate of MFT feed	167,312	t/y	33.46	t/h
Operating hours per year	5,000			

Table 8

The on stream time of 5,000 hours per year will be conservative in later years. In the first two to three years, this is considered to be reasonably realistic given the learning curve for a new process in the area. As the on stream factor improves, the plant will be capable of producing more than 22,000 tonnes of product per year.

6.2 Flowsheet

The flowsheet has been developed from the initial bench scale testing, pilot plant work and discussions with equipment vendors familiar with kaolin processing.

Mature Fine Tails would be pumped at a rate of 28 m^3/h to attrition cells. Sodium silicate would be injected into the pipe prior to the attrition cells. Product from the attrition cells would flow to a primary clarifier, where bitumen will be floated off. The bitumen will flow to a tank before being pumped back to extraction. Clarifier underflow, including a mixture of clay and silt would be pumped to a secondary thickener.

Thickener underflow is mostly silt, and would be returned to tailings ponds. Thickener overflow would be mostly clay slurry, with some bitumen. The thickener overflow tank would have a set level, with an overflow to the bitumen return tank. The remainder of the thickener overflow will be pumped to a drum filter. An alternate, but more expensive arrangement is to use New Logic's V*Sep filters. This can be investigated further at the next level of detail.

The purpose of the filter is to produce a wet filter cake (50% solids) which is actually pumped to a spray dryer. The heating medium in the spray dryer is off gas from the calciner. Dried clay, surface dry but still containing water of hydration, is reportedly free flowing, and will be conveyed to a multiple hearth calciners. Calcined clay should be free running, but a hammermill is provided in case of agglomeration.

6.3 Equipment

The equipment list is contained in Table 9:

KAOLIN RECOVERY PLANT						
			FLOWSHEET		DESIGN (MAX.)	
UNIT #	STREAM	DESCRIPTION	DUTY	UNITS	DUTY	UNITS
PP-01	1	MFT Transfer Pump	28.34	m^3/h	35	m^3/h
PP-02	2	Dispersant Metering Pump	0.06	m^3/h	0.15	m^3/h
ML-01	3	Attrition Mill	28.39	m^3/h	35	m^3/h
TH-01	3	Primary Clarifier	28.39	m^3/h	35	m^3/h
TK-01	4	Bitumen Storage Tank			50	m^3
PP-03	4	Bitumen Transfer Pump	1.90	m^3/h	5	m^3/h
PP-04	5	Clarifier Underflow Pump	26.49	m^3/h	30	m^3/h
TH-02	5	Thickener	26.49	m^3/h	30	m^3/h
PP-05	6	Thickener Underflow Pump	3.40	m^3/h	7	m^3/h
TK-02	7	Thickener Overflow Tank			60	m^3
PP-06	7	Kaolin Slurry Pump	23.09	m^3/h	30	m^3/h
FL-01	7	Filter	23.09	m^3/h	30	m^3/h
PP-07	8	Filtrate Pump	16.59	m^3/h	25	m^3/h
PP-08	9	Filter Slurry Pump	9.35	t/h	10	t/h
DR-01	9	Dryer	9.35	t/h	10	t/h
CR-01	10	Hammermill	4.72	t/h	7	t/h
CV-02	10	Dry Kaolin Conveyor	4.72	t/h	7	t/h
CC-01	10	Calciner	4.72	t/h	7	t/h
CR-02	11	Hammermill	4.58	t/h	7	t/h
		Total Costs				

Table 9

PP-01 Slurry Pump	3/2 slurry pump with 10 HP motor
PP-02 Dispersant Metering Pump	Positive displacement pump
ML-01 Attrition Cell	Four Wemco #120 cells, total volume 13.5 m^3
TH-01 Primary Clarifier	6.25 metre diameter, steel tank
TK-01 Bitumen Storage Tank	
PP-03 Bitumen Transfer Pump	2/1-1/2 slurry pump with 5 HP motor
PP-04 Clarifier Underflow Pump	3/2 slurry pump with 10 HP motor
TH-02 Thickener	16 metre diameter, steel tank
PP-05 Thickener Underflow Pump	2/1-1/2 slurry pump with 5 HP motor
TK-02 Thickener Overflow Tank	
PP-06 Kaolin Slurry Pump	3/2 slurry pump with 10 HP motor
FL-01 Filter	One 6 ft diameter x 8 ft wide drum filter
PP-07 Filtrate Pump	3/2 slurry pump with 10 HP motor
PP-08 Filter Slurry Pump	3/2 slurry pump with 10 HP motor
DR-01 Dryer	GEA Niro 20’8” diameter x 16’ cylindrical height
CV-02 Dry Kaolin Conveyor	
CC-01 Calciner	Hankin 25’9” five hearth furnace
CR-01 Hammermill	30” diameter

6.4 Capital Cost

The estimated capital cost is shown in Table 10. The major equipment has been sized and priced from data supplied by vendors with experience in clay processing. Bulk materials and the cost of installation labour was prorated from current, similar projects. The labour rate and indirect cost (expressed as $/hour of direct labour) are current for projects in Alberta. Engineering, Procurement and Construction Management were calculated as a percentage of field costs.

	Equipment	Labour		Total
Description	**& Materials**	**Hours**	**$**	**$**
Direct Costs	$16,734,000	104,600	$4,184,000	$20,918,000
Indirects			$5,020,800	$5,020,800
Total Field Costs				$25,938,800
EPCM				$4,666,800
Total Project Costs				**$30,605,600**

Table 10

6.5 Operating Cost

The operating costs have been developed using current pricing for gas, power and reagents. No allowance has been made for fuel credits from bitumen which remains with the clay. There will also be an opportunity to recirculate calciner offgas to reduce the dryer fuel required, but this has not been included. Table 11 contains the operating costs.

Operating Costs			22,000	t/y	
	Quantity	**Unit**	**$/unit**	**$/y**	**$/t**
Manpower	22		$120,000	$2,600,000	$ 118.18
Reagents	283	t/y	$ 200.00	$56,680	$ 2.58
Natural Gas	134,535	GJ/y	$ 2.00	$269,069	$ 12.23
Power	699	kW	$ 0.044	$153,780	$ 6.99
Maintenance	8%	Equip.	$7,530,325	$602,426	$ 27.38
Total				**$ 3,681,956**	**$ 167.36**

Table 11

The operating cost is estimated to be $167.36 per tonne of product.

7.0 CONCLUSIONS AND RECOMMENDATIONS

1. Syncrude Mature Fine Tails can be separated into streams of bitumen, kaolinite-rich clay and silica by the addition of dispersant. A concentration of 0.2% to 0.3% sodium silicate, well mixed, is effective in floating bitumen and settling silica.
2. Upgraded clay containing 31% alumina has been prepared at the pilot plant. Providing acceptable mixing of dispersant is achieved, the commercial scale plant should be capable of producing a clay containing >30% alumina on a consistent basis.
3. The process route is relatively simple. Once a mid-clay has been separated, the downstream equipment is standard to the clay processing industry.
4. The capital cost of a 22,000 tonne per year plant is estimated to be $30.6 million for a design-build contract, plus $1.25 million for owner's project costs.
5. The operating cost is estimated to be $3.7 million per year, or $167 per tonne of calcined clay.

6. A simplified cash flow analysis based on a selling price of $600 per tonne, minus $60/t freight, indicates a pre-tax rate of return of 20% and a net present value, at 10% discount rate, of $156 million.
7. The capital and operating costs are considered conservative. The plant has been sized for 5,000 hours per year, but will be capable of operating for 7,000 hours per year after about three years. Fuel costs do not include a credit for energy in bitumen carried forward with clay, or for offgas from the calciner recycled to the dryer.
8. The next level of pilot plant work should use scaled down equipment to replicate the front end mixing and initial separation. This will provide design data on mixing energy input, residence time, and the primary clarifier upflow rate of bitumen and settling rate of silica.