A COMPARISON OF KAOLIN FROM NOVA SCOTIA AND SOUTH-WEST ENGLAND

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A recent exploration programme involving geophysics (resistivity and gravity) and a detailed drilling campaign has identified a kaolin and quartz deposit in the Yarmouth area of Nova Scotia, Canada. At present Canada is a major paper producer and imports approximately 0.8 Mt of high quality filler and coating kaolin, there being no suitable Canadian source available. Resources of 5 Mt have been identified and, based on the gravity survey; this tonnage can be significantly increased. The kaolin is derived from a granite and the yield is >32 weight % at <45 μm refining. Work is currently being carried out on beneficiation by hydrocyclones and centrifugal separation. In examining the coarser fractions a stacky kaolinite is identified. Some flotation trials to separate out the kaolin stacks, followed by delamination to produce high aspect ratio kaolin is being explored for supercalendered (SC) papers. Brightness improvement trials are being carried out utilizing reductive bleaching and magnetic separation and initial results are encouraging. Other markets are being studied for use in other types of paper, ceramics and specialities (paint, rubber and plastics). Comparisons of the clay from Nova Scotia are made with kaolin from Devon and Cornwall with respect to the chemistry, mineralogy, morphology and physical properties. A 10,000 t bulk sample of the quartz from the Nova Scotia deposit was collected in late 2000, and flotation trials on the mica residue from the kaolin beneficiation processes are being studied for their commercial properties. The Yarmouth kaolin deposit represents a good opportunity for Canada to have its first commercial production of high quality material for various markets. This paper presents progress to date as the research work is still continuing.

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INTRODUCTION

Canada is a major paper producer and imports approximately 0.8 Mt per annum of high quality kaolin for paper filler and coating. In this paper a description will be given of the exploration and evaluation of the Yarmouth kaolin prospect of Nova Scotia, which shows potential as a source of kaolin for the local markets (MacDonald, 2001). Previous exploration in the area for kaolin had been concentrated on the Early Cretaceous non-marine sediments of the Musquodoboit River Valley, south of Truro (Figure 1), where the Nova Scotia Department of Natural Resources and Kaoclay Resources Ltd sunk more than 200 cored boreholes, but these deposits have not yet been developed (Finck and Stea, 1996; Stea *et al.,* 1996; Scott and Stea, 2002). The Yarmouth deposit is situated in the south-western part of Nova Scotia 40 km north-east of the port of Yarmouth and 45 km north-west of Shelburne (Figure 1). Previous work in the area during the late 1970s and early 1980s consisted of exploration for base metals by a number of companies including Shell Canada Ltd (Minerals Division), Billiton Canada Ltd and Esso Minerals. During 1990-1996 the claim block was included in a regional mapping project conducted by the Nova Scotia Department of Natural Resources (MacDonald and Ham, 1994). During these, and various other exploration programmes, kaolinised granite was encountered leading to the property being optioned to Black Bull Resources Incorporated in 1998.

GEOLOGY AND EXPLORATION

The Yarmouth kaolin property is located within the Meguma Terrane, a suspect terrane of the Canadian Appalachian Orogen (Williams and Hatcher, 1983). The area consists of regionally deformed Cambro-Ordovician turbidites that have been intruded by Late Devonian to Early Carboniferous plutons. The geology of the South Mountain Batholith, including the Davis Lake Pluton which hosts the Yarmouth kaolin deposit, has been described in detail (MacDonald *et al.,* 1992). The central portion of the property is underlain by a 100 to 200 m wide, northeast-trending, quartz-kaolinite breccia zone, which dips at approximately 40 to 70 degrees to the southeast. The zone has developed along a major shear (Tobeatic Shear Zones) and has been traced north to the Clyde River and south to Frog Pond, a distance in excess of 7 km (Figure 2).

The core of the zone is occupied by a 25 to 75 m wide zone of high purity brecciated quartz. The kaolinised zone forms the footwall to the quartz breccia, dipping to the southeast and varying in width from 15 to 30 m. Kaolinitic bearing zones also

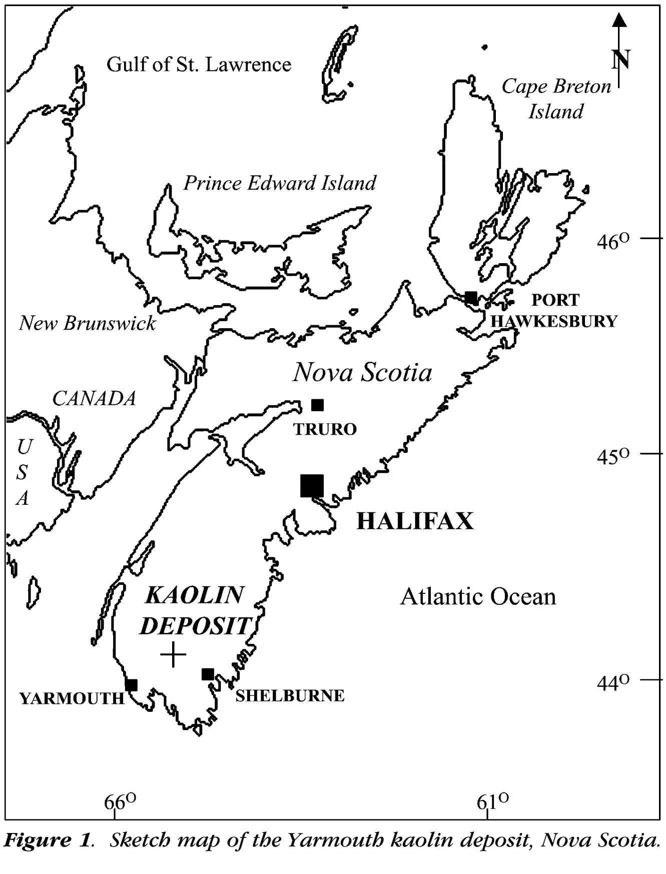

***Figure 1**. Sketch map of the Yarmouth kaolin deposit, Nova Scotia.*

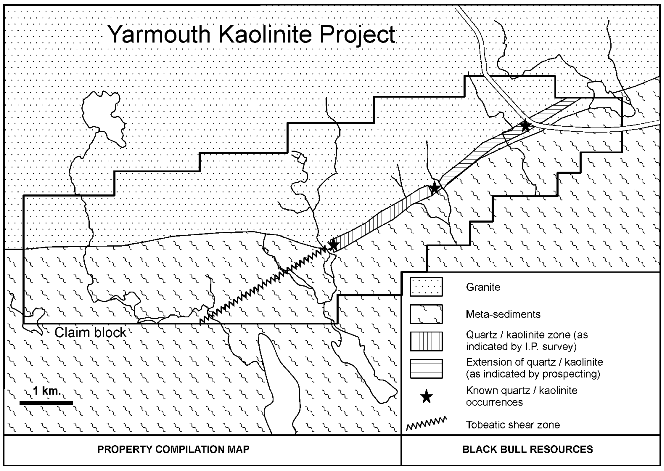

Figure 2. *Geological sketch map of the Yarmouth kaolin deposit, Nova Scotia.*

overlay the quartz breccia, forming a hanging wall along the south-easterly portion of the zone. The kaolin zone varies in width from 5 to 60 m and has a whitish colour. The kaolin is found in both a brecciated quartz zone and also in an altered granite that exhibits little brecciation. The zone of the quartz brecciation has been traced along the strike of the shear zone by resistivity and the kaolin zone shows a distinct anomalous gravity low, which will be useful in identifying new areas for drilling. To date 30 holes have been drilled, some to depths of 150 m and more, and kaolinised granite is still being encountered at these depths. Provisional resources of 5 Mt of kaolin have so far been identified and, based on the gravity survey, this tonnage can be significantly increased. Samples of the kaolin core have been collected and tested by a number of laboratories worldwide, for their commercial clay properties. In addition to the kaolin, quartz has been bulk sampled and evaluated for a number of markets. Work is also continuing on the market potential of the mica.

TEST RESULTS OF THE KAOLIN

Some seventy samples have been tested so far to determine the quality of the Yarmouth kaolin. A typical result of some of the physical, chemical and mineralogical test results are shown in Table 1. The kaolin exhibits a pseudohexagonal morphology typical of kaolinite and in the coarser fractions ($>10\ \mu m$) there are a large number of stacky particles of kaolin. The kaolin shows a good response to bleaching and magnetic separation indicating that some of the iron is present as discrete particles, rather than within the lattice. Chemically, the kaolin is high in potash that is reflected in the high mica content of 11% indicating that the fine mica is a similar particle size to the kaolin and has not been separated. There is also 2% of feldspar that contributes to the potash. Further refining and processing will remove the small amounts of quartz and feldspar. The yield of kaolin from the matrix is high for a kaolinised granite at 32%. Work is continuing on evaluating further borehole and bulk trench samples.

PROCESSING TRIALS

A 60 kg representative sample of kaolinised granite taken from the trial pit has been investigated to determine the commercial viability of the deposit. The matrix was first processed by blunging into a slurry to separate out the coarse quartz, feldspar and coarse mica. The resultant mixture of dominantly kaolin, some mica and fine sand was subjected to a series of refining trials to separate and collect particles of different size. Hydrocyclones separated out the fine kaolin from the sand and mica while a centrifuge was utilised to separate the finer kaolin from the coarser kaolin generated from the hydrocyclone stage. The samples generated from these separation processes have been further evaluated physically and chemically for their suitability in paper, ceramics and other uses. The coarser underflows from the centrifuge and hydrocyclone were then subjected to a series of flotation trials to remove the coarser, very fine sand and some mica and leave dominantly kaolin. The morphology of the kaolin in the coarser fractions proved to be stacky so the material was then placed in laboratory sand grinding equipment to delaminate the kaolin into platier material. The resultant fractions were then passed through a hydrocyclone to give the delaminated products. This delaminated kaolin, with a high aspect ratio, is suitable for use in supercalendered paper production. The changes in morphology of the kaolin with the varying processes are shown in Figure 3.

Property	
Yield of kaolin at <45 μm refining	32%
Results of kaolin refined to <10 μm	
Wt.% >10 μm	15%
Wt.% <2 μm	50%
ISO Brightness (unbleached)	82.0
ISO Brightness (bleached)	84.0
ISO Brightness (magnetic separation)	87.5
Flow (wt.% solids)	69.4
Viscosity Concentration (wt.% solids)	71.7
Chemistry (wt.%) by XRF	
SiO_2	48.2
Al_2O_3	36.4
Fe_2O_3	0.9
TiO_2	0.1
CaO	0.1
MgO	0.3
K_2O	2.1
Na_2O	0.1
L.O.I.	11.5
Mineralogy (wt.%) by XRD	
Kaolinite	84
Mica	11
Quartz	2
Feldspar	2

Table 1. *Physical, chemical and mineralogical results of the Yarmouth kaolin.*

PROPOSED FLOW SHEET

The preliminary processing trials indicate that a delaminated kaolin with a high aspect ratio can be produced from the Yarmouth kaolin deposit. This is similar to the type of kaolin produced from the St. Austell Granite in Cornwall (Bristow, 1995). A finer product is also produced which is being evaluated as a coating pigment and for use in performance minerals (paint, rubber and plastics). An outline flow diagram for production of kaolin from the Yarmouth kaolin deposit is shown in Figure 4 and indicates that either a wet or drying mining process can be used. No decision has yet been taken on the method of mining but it is likely to be dry mining. Following the laboratory trials the next step will be to carry out some pilot plant trials.

COMPARISONS BETWEEN SOUTH-WEST ENGLAND AND NOVA SCOTIA

A summary of some comparisons between kaolinised granites from the St. Austell Granite, Cornwall and the Yarmouth kaolin deposit, Nova Scotia is shown in Table 2. Both areas show a wide range of granite types with both older and younger types. The age of the granites is different with the South Mountain batholith dated at 370 My and the Cornish batholith dated at 290 My. The

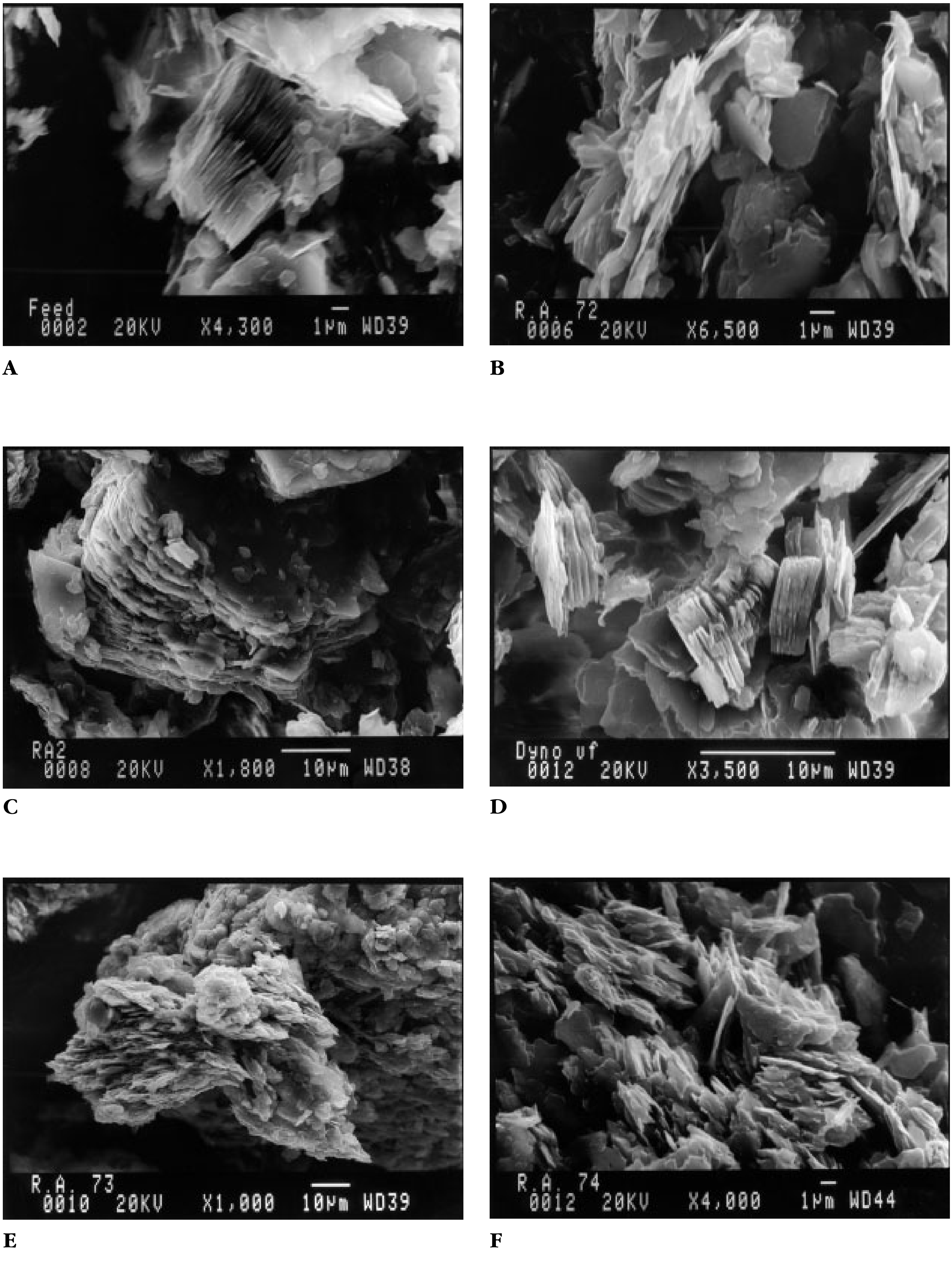

Figure 3. *Scanning electron photomicrographs showing the morphology of the kaolin feed and processed clays from Yarmouth. (A) Feed clay. (B) Dynoclone product from hydrocyclone overflow. (C) 2" hydrocyclone underfeed. (D) Dynocone underflow from hydrocyclone overflow. (E) Cyclone overflow of floated and ground preliminary cyclone underfeed product. (F) Cyclone overflow of floated and ground dynoclone underfeed product.*

Area	St. Austell, Cornwall	Yarmouth, Nova Scotia
Type of granite	"Older" - biotite granite "Younger" - Lithium mica	"Older"- biotite monzogranite "Younger"- 2 mica monzogranite
Type of mining	Wet - high pressure monitor	Planned dry mining/maybe wet
Number of Mines	25	1 or 2 planned
Age of granites (M y)	280 - 290	370 (MacDonald et a.l, 1992)
Surface kaolinisation	40 km^2	2 km^2
Resource (Million t)	>100?	10 (Estimate)
Depth of kaolinisation	Up to 300 m	Up to 250 metres
Nature of deposit	Funnel shaped and widespread	Fault controlled zone of alteration
Variation with depth	Some variation	Decreasing kaolinisation
Veinlets/lodes	Sheeted vein systems with tin mineralisation	10-20 m wide quartz lodes, tin mineralisation nearby
Yield of kaolin from Matrix	10 - 15%	25 - 32%
Main clay mineral	Kaolinite	Kaolinite
Other minerals mined	Building Sand	Quartz
Kaolinite morphology	Pseudo-hexagonal Well crystalline	Pseduo-hexagonal Well crystalline
Aspect Ratio	Variable - platy and blocky	Variable - platy and blocky
Accessory minerals	Trace-montmorillonite	Sericite and primary mica
Typical Chemistry wt.%		
TiO_2	0.01 - 0.03	0.10
Fe_2O_3	0.40 - 1.0	0.8 - 1.2
K_2O	1.0	1.0 - 2.5
MgO	0.25	0.20 - 0.40
Quality	Wide range of quality covering all major markets up to 88 ISO Brightness	Wide range of quality covering all markets with up to 87.5 ISO Brightness
Production	2,500,000 tpa	None, 250,000 tpa planned
Major Markets	Paper 75% Ceramics 15% Performance Minerals 10%	Planned production mainly for paper with some for ceramics and Performance Minerals
Export	85%	Mainly Canadian/USA Market
Employees	2900	200 (Projected)
Proximity to Ports	Adjacent	40 km

Table 2. *Comparisons between kaolinised granites from St. Austell and Nova Scotia.*

kaolinisation in Cornwall and Devon covers a wide area and is controlled in some areas by structure (sheeted vein systems), whilst in some cases the alteration is pervasive and unrelated to structure. In the Yarmouth area the kaolinisation is restricted to a narrow zone associated with quartz brecciation and a fault zone. The morphology of the kaolin is similar in both areas with a distinct pseudo-hexagonal morphology at the fine particle size ($<5\mu$m) and stacks of kaolinite in the coarser fraction ($>10\mu$m). The alteration of the Yarmouth granite gives a high yield of up to 32% as against 10-15% from Cornwall. This has significance for the development of the Yarmouth kaolin deposit, as there will be less waste. Chemically, the Cornish kaolin has lower iron and titania with the higher levels of the Yarmouth material limiting its utilisation in high quality tableware and porcelain. Both the granites of Nova Scotia, particularly in the Yarmouth area, and Cornwall are associated with tin mineralisation. The Yarmouth kaolin deposit is approximately 10 km southeast of the East Kemptville tin deposit (which was mined from 1985 until 1992). The collapse of the tin price led to the curtailment of tin mining in both Nova Scotia and Cornwall. One of the major users of kaolin in Canada is the Stora Enso paper mill at Port Hawkesbury in Nova Scotia (Figure 1). They produce a supercalendered (SC) paper utilising up to 150,000 tpa of a platy kaolin imported from Cornwall. The deposit at Yarmouth has the potential to produce a similar type of product and this is what is driving the project forward. Kaolin resources in the Yarmouth area are much less than in Cornwall but exploration is still at an early stage. It remains to be seen whether the Yarmouth kaolin prospect will become an important producer in the near future to compete with imported kaolin from Cornwall.

SUMMARY

Preliminary studies of the Yarmouth kaolin prospect show it has a high yield of 32% at $<45\ \mu$m refining with a coarse stacky morphology in the $>10\ \mu$m fraction and a finer more euhedral kaolin in the $<10\mu$m fraction. The coarse stacky kaolin has been subjected to a flotation process, to remove quartz and feldspar, and then delaminated to transform the stacks into platy kaolinite particles with high aspect ratios. The platy kaolinite formed from the processing of the stacky kaolinite has the potential to be used as a paper filler in supercalendered paper.

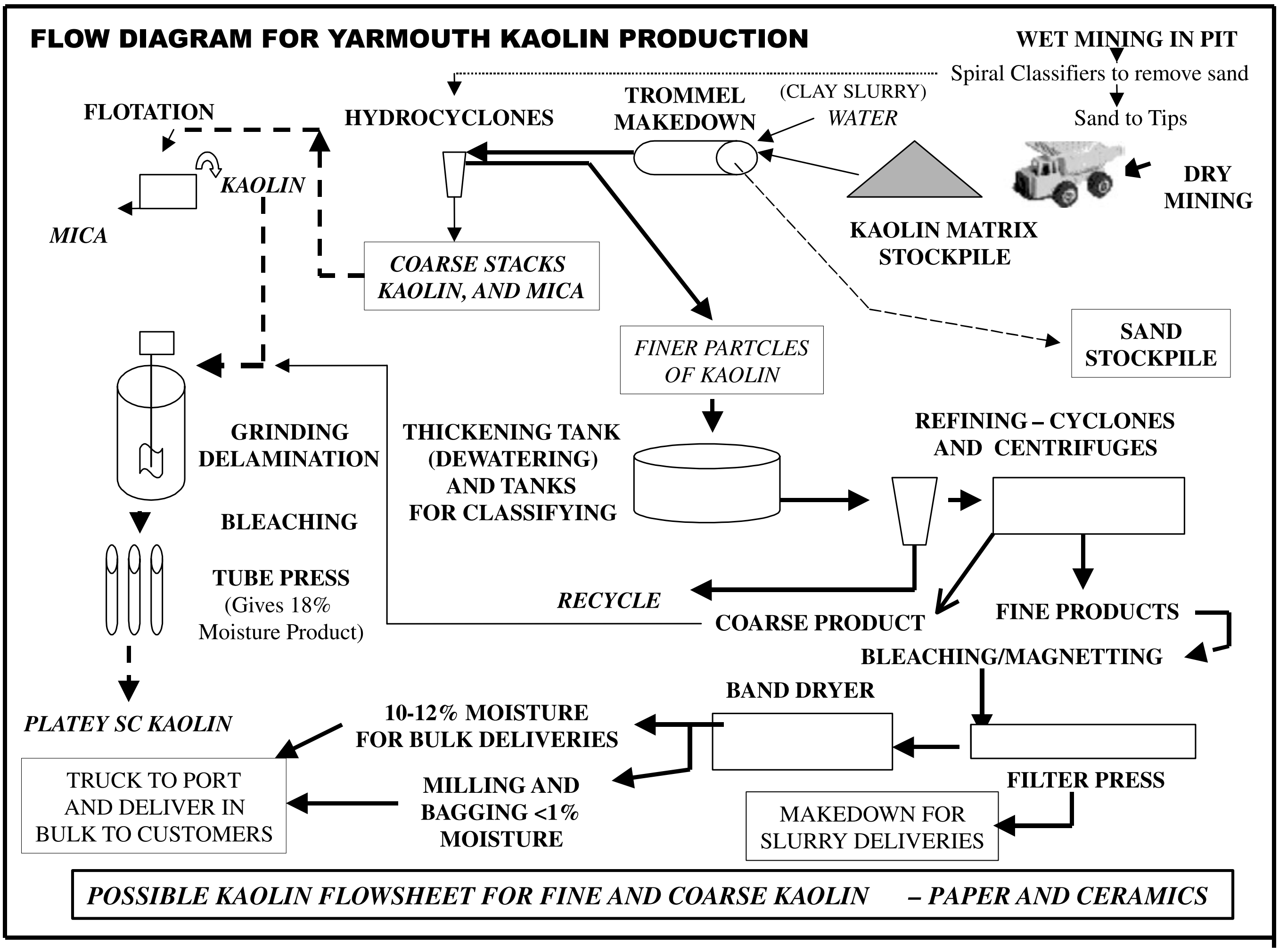

Figure 4. *Potential Flow Sheet for the Yarmouth Kaolin to produce fine and coarse grained kaolin products*

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