CURRENT WORLD STATUS OF KAOLIN FROM SOUTH-WEST ENGLAND

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In 2001, Cornwall and Devon produced 2.5 Mt which represents approximately 10% of the world's total output of 24.4 Mt of high quality kaolin. Imerys dominates with 88% of kaolin sales from south-west England with Goonvean (8%) and WBB Minerals (4%). The market sectors served are dominated by paper (75%) with ceramics (13%) and performance minerals (12%). In the face of increasing competition from other kaolin deposits in the world, particularly Brazil, and the use of other pigments such as ground calcium carbonate and precipitated calcium carbonate in paper, the china clay industry in south-west England has been under attack. However, with the development of a new range of products for paper (based mainly on "engineered" materials), ceramics and performance minerals (paint, rubber and plastics) the future of the industry looks positive based on remaining proved reserves for at least another 50 years, good logistics, technological processing skills, and proximity to markets. This paper reviews the industry as it is in early 2003 and looks at some of the threats posed by kaolin from the Amazon Basin and other pigments such as ground calcium carbonate and precipitated calcium carbonate.

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INTRODUCTION

The production of china clay (kaolin) in 2001 from Devon and Cornwall, south-west England, was 2.5 Mt and represents approximately 10% of the world's output. There are three companies now producing kaolin in Devon and Cornwall: Imerys, Goonvean and WBB Minerals. Imerys, a French company, took over the operations of ECC International Ltd (ECC plc) by acquisition in 1999 and now accounts for 25% of the world's total kaolin production of 24.4 Mt with operations in both Devon and Cornwall in addition to those in Brazil, USA, Australia and New Zealand. Goonvean remains the only English producing company, based on its operations in Cornwall, with WBB Minerals (now part of the Belgium Sibleco Group) operating in Devon. Clay bearing ground in mid Cornwall covers 40 km^2 and there are approximately 9 t of waste rock and debris produced for 1 t of kaolin product. Over 60 grades of kaolin are produced in Cornwall and 87% is exported, 30% through the port of Par and 70% through Fowey. The sales of kaolin from Devon and Cornwall are dominated by Imerys with 88%, with Goonvean (8%) and WBB Minerals (4%). Sales of kaolin from Devon and Cornwall are dominated by the paper market with 75%, ceramics 13% and performance minerals 12% (mainly for paint, rubber and plastics). This paper reviews the history of the china clay industry since kaolin was first discovered at Tregonning Hill by William Cookworthy in 1746, the geology of the kaolin deposits, resources of kaolin, operating china clay companies and their production capacities, some of the new products and how they are processed and some information on competition from Brazilian kaolin and other pigments being used in paper.

HISTORY OF THE CHINA CLAY INDUSTRY

Since the discovery of china clay in 1746 at Tregonning Hill near Helston, Cornwall by William Cookworthy there has been uninterrupted mining and processing for a wide range of markets. Some of the major china clay industrial developments are shown in Table 1 (Bowditch, undated).

Initially the china clay (synonymous with kaolin) was utilised in porcelain and tableware and from the early 1900s mainly in paper as a filler and coating pigment. In 1891 kaolin production exceeded 0.5 Mt for the first time and by 1900, 60% of the sales were for the paper industry. Kaolin production from 1748 to 2001 is shown in Figure 1 and highlights a peak in 1988 of 3.28

YEAR	CLAY INDUSTRY EVENT
1746	Discovery of China Clay at Tregonning Hill by William Cookworthy
1748	Cookworthy finds clay at Carloggas, Near St. Stephens, St. Austell
1768	Cookworthy takes out Patent for porcelain manufacture
1775	Porcelain patents modified to allow Staffordshire potters into Cornwall
1807	Mention of clay being used in paper manufacture
1830	Clay working at Lee Moor, Dartmoor commenced by John Dickins
1840	Par Harbour, new major port facility is completed by Joseph Treffry
1858	First detailed listing of clay works records 65,600 tonnes produced
1860	Commencement of china clay working on Bodmin Moor near Blisland
1878	First clay washing experiments using hoses carried out at Dubbers Pit
1891	Industry exceeds 500,000 t for first time
1900	561,000 t produced, 60% for the paper industry.
1912	Pre-war production highest figure achieved at 874,000 tonnes
1923	First chemically refined clays introduced
1932	ECLP & Company formed by acquisition of John Lovering and H.D. Pochin
1934	Launch of the coating clay SPS
1936	ECLP commissions 11.25MW coal fired power station at Nanpean
1939	First Rotary drier introduced by ECLP
1946	First electron microscope used in industry
1954	First commercial centrifuges introduced for the production of paper clays
1964	2 million tonne milestone is reached
1969	Introduction of flotation into the process
1977	Tube presses introduced at Burngullow
1985	Opening of Old Pound pit, the first new pit since before World War II
1999	English China Clays plc merges with IMETAL to form a global company
2000	IMETAL renamed as IMERYS

Table 1. *Major events in the china clay history of south-west England (after Bowditch, undated).*

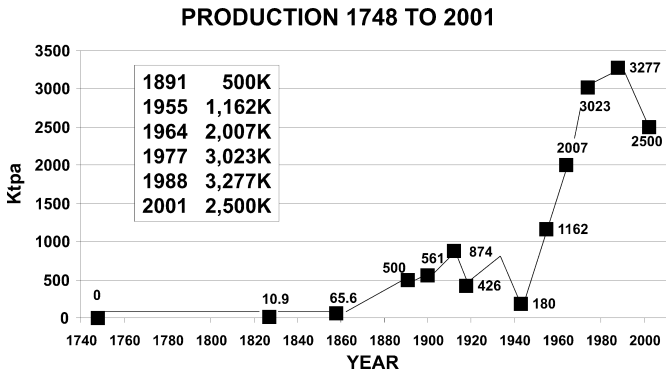

Figure 1. *Production of china clay from Devon and Cornwall from 1748 to 2001.*

Mt. It is estimated (Bowditch, pers. comm., 2002) that the production of kaolin since 1830 has been 170 Mt with a value (at current day prices) of £13.5 Billion. This can be compared with a total value of £9.5 Billion for the 4.5 Mt of copper and tin mined in south-west England.

Geology of the kaolin deposits

The geology and kaolinisation of the St. Austell and other granites in Devon and Cornwall have been described in great detail elsewhere (Alderton and Rankin, 1983; Allman-Ward, 1985; Allman-Ward *et al.,* 1982; Bray and Spooner 1983; Bristow, 1995; Bristow and Exley, 1994; Bristow *et al.,* 2002; Exley, 1959, 1976; Halliday, 1980; Manning *et al.,* 1996; Psyrillos *et al.,* 1998, 1999; Sheppard, 1977). In the St. Austell area there are a number of granite types such as biotite granite, tourmaline globular quartz granite, fine-grained tourmaline granite, lithium mica granite and a topaz bearing granite (Figure 2). A general East-West cross section of the St. Austell Granite is shown in Figure 3. China clay deposits are usually funnel-shaped with a typical cross-section shown in Figure 4. Many of the kaolin pits show sheeted quartz tourmaline vein systems with some tin and tungsten minerals present. A summary of the complex alteration story of the St. Austell Granite is in Table 2.

Resources of kaolin

The total resource of kaolin in south-west England from all the kaolinised granites is not known. Over the past few years Imerys has carried out a detailed drilling programme using a reverse circulation EDECO rig. 100 m per 12 hour shifts were achieved and all core was sampled and tested every 5 metres for mineralogy (% of kaolin, quartz, mica and other accessory minerals). Economic cut-off levels established ensure that no kaolin is rejected as so often happened before with previous methods of evaluating a kaolin deposit. Additional drilling has also been carried out filling

Age (MY)	Granite types, alteration and mineralisation
285	Intrusion of biotite granites
275	Lithium mica, globular quartz, topaz granites
270	Main Sn and W mineralisation Sheeted vein systems – mainly quartz tourmaline Tourmalinisation and greisenisation
240	Cross course mineralisation – Pb and Zn
200 - 25	Alteration continues driven by high radiogenic circulation (granites naturally high in uraninite >20 ppm U). Pervasive kaolinisation?
Present	High heat flow still active – basis of hot dry rock project for geothermal energy.

Table 2. *Granite types, alteration and mineralisation of the St. Austell Granite with ages (MY).*

AREA	PIT NAME	WEEKLY TONNAGE	KAOLIN GRADES
ST. AUSTELL GRANITE - 77% OF PRODUCTION			
Central	Blackpool Goonbarrow/Rocks Dorothy-Littlejohns Gunheath (temp. closed)	6,000 6,000 10,000 5,000	Mainly paper and performance minerals. Source of much of the stacks of kaolin for delamination.
Western	Melbur-Remfrey Treviscoe	5,000 500	Ceramic area but also for paper. Ceramics.
DARTMOOR GRANITE - 18% OF PRODUCTION			
Lee Moor	Lee Moor, Whitehall Yeo, Cholwichtown	7,500	Low Fe clays for porcelain products and feed for calcinations(for paint and plastic products).
BODMIN MOOR GRANITE - WAS 5% PRODUCTION - PITS NOW CLOSED			
Bodmin	Stannon and Park	2,000	Platy clay for paper, higher iron

Table 3. *Typical weekly production of kaolin from Imerys pits in 2000.*

in gaps for detailed mine plans to be prepared. The objective for Imerys is to publish a resource/reserve statement in the Annual Report. Resources and reserves are based on the JORC (Joint Ore Reserves Committee of the Australasian Institute of Mining & Metallurgy) code and includes inferred/indicated/measured resources and probable and proved ore reserves.

Kaolin resources in Devon and Cornwall from the Dartmoor and St. Austell granites have been estimated at >125 Mt, sufficient for at least another 50 years at current rates of exploitation. In addition there are an estimated 60 Mt of tailing residues in the mica dams which contain stacks of kaolin which could yield another 20 Mt of delaminated products. There are also additional resources of kaolin in the Land's End, Carnmenellis and Bodmin Moor granites although there are no future plans by Imerys to mine in these areas.

The operating china clay companies

Imerys operates 14 pits in Devon and Cornwall (11 in the St. Austell area), Goonvean 4 pits in Cornwall and WBB Minerals operates two pits at Lee Moor, Dartmoor, Devon. Sales of kaolin from Devon and Cornwall for the period 1995 to 2001 are shown in Figure 5. The sales of kaolin from Devon and Cornwall in 2001 were 2.5 Mt with Imerys accounting for 88%, Goonvean 8% and WBB Minerals 4%. The main areas now mined are restricted to the St. Austell and Dartmoor granites. Mining on Bodmin Moor ceased in 2001 and there has been no activity for several decades from other areas.

Imerys

A typical weekly production from Imerys pits (Table 3) shows that 77% is from the St. Austell area with 18% from Lee Moor (Dartmoor Granite) and 5% from Bodmin Moor (Stannon and Park - mining has now ceased from these pits).

Details of the general processing of china clay in Cornwall are well described elsewhere (Thurlow, 2001; Bristow and Exley, 1994: Bristow *et al.,* 2002). Over the last two decades additional processes have been developed to improve the quality of the kaolin. For brightness enhancement, superconducting magnets

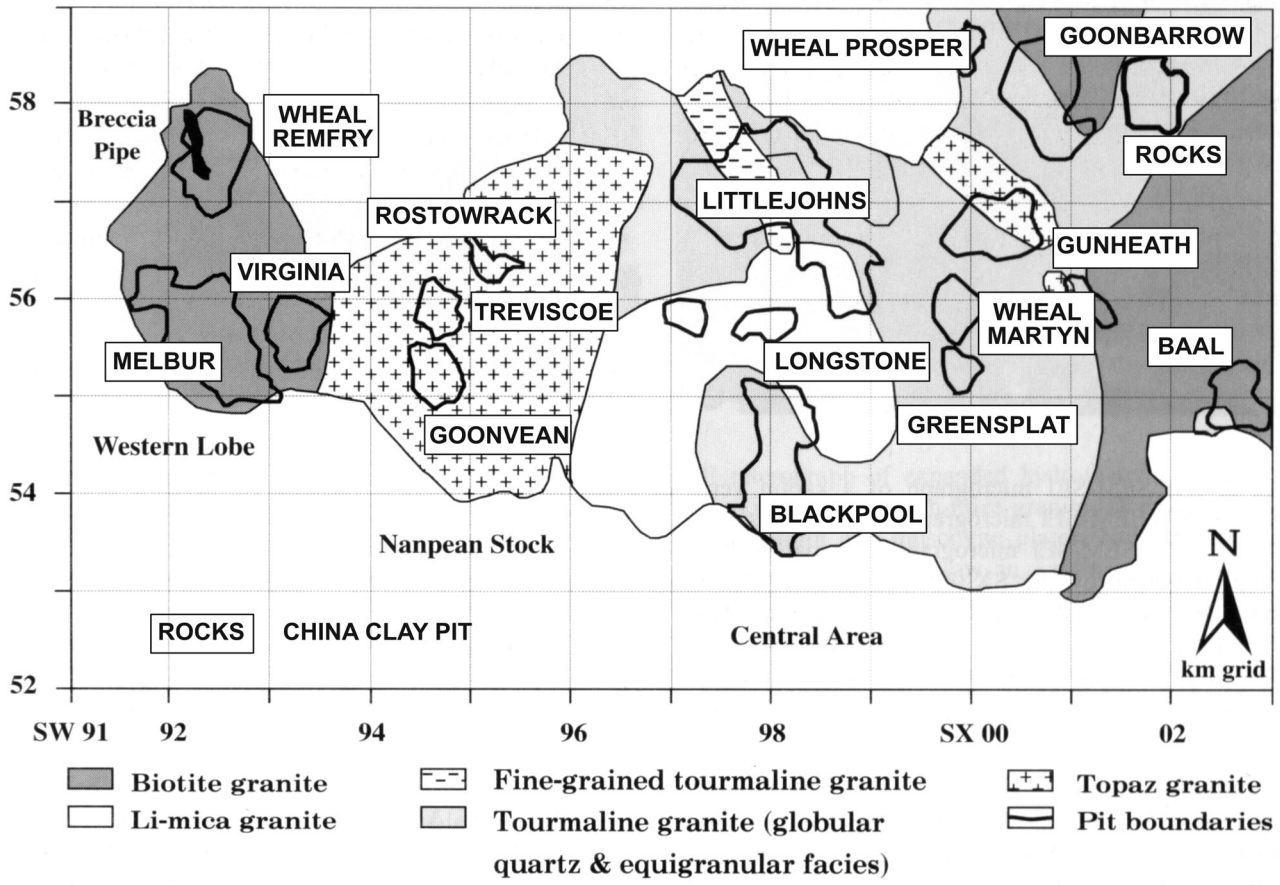

Figure 2. *Geological map of the St. Austell area showing the different types of granite and some of the clay pits.*

have been introduced alongside the high intensity magnetic separators (HIMS). Froth flotation, selective flocculation and selective separation processes to remove abrasive materials such as quartz and feldspar have been utilised. Systematic petrographic studies (Psyrillos *et al.,* 1999) indicate that kaolin occurs in the form of two textural types: (i) finely crystalline kaolin typically <5 μm in average diameter), which infills dissolution porosity of granitic feldspars, and (ii) coarsely crystalline vermiform (worm like) aggregates up to 100 μm or more in length, which are closely associated with expanded micas. The vermiform aggregates are characterised by an intergrowth of mica and kaolin crystals, which can be examined by TEM. It is suggested that the expanded mica texture is probably the result of preferential precipitation

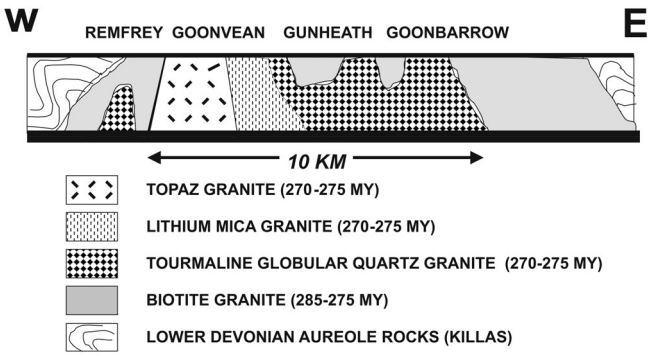

Figure 3. *A10 km west-east cross section of the St. Austell area showing the different types of granite.*

UK (ISO Brightness)		North America (GE Brightness)		Brazil (GE Brightness)	
Engineered Pigments		Coating Regular Brightness		Engineered Pigments	
Suprastar	88.5	Fine #1 Astra Glaze	88.0	Capim DG	90.5
Supraprint	88.5	#1 Premier	88.0	Capim GP	90.5
Coating High Brightness		Delaminated		Coating High Brightness	
Suprawhite 95	88.0	Astra Plate	86.0	Delaminated	
Suprawhite 80	87.5			Capim NP	90.5
				Capim CC	89.0
Coating Regular Brightness					
SPS	85.5				
Ultra Platey Coating					
Supraplate	86.5				
Suprasmooth	83.0				

Table 4 . *Imerys range of paper coating clays with brightness data from UK, USA and Brazil (GE Brightness 1.5-2.0 points higher than ISO Brightness).*

of kaolin along mica cleavage planes and is not simply a process of chemical replacement. The most significant processing development over the last decade has been the production of delaminated clays from these vermiform, or stacky, kaolinites. Refiners (local name for processing plants) at Goonbarrow, Goverseth and Trebal concentrate on the delamination of kaolin stacks to give a range of platiness. For the pigments and additives group (paper and performance minerals - since January 2003 has been reorganised into separate paper and speciality groups) approximately 60% of the processed kaolin is now delaminated. The flow sheet at low abrasion plants involves flotation to remove contaminants (feldspar, quartz, mica) and a sand grinder (known as a sand grinder as it formerly utilised a round resistant sand as the grinding medium but now a ceramic bead is the preferred medium) for delamination (Psyrillos *et al.*, 1999).

The aspect ratio of the resultant delaminated kaolin is an important parameter and Imerys have developed a stop flow conductivity measurement instrument which gives a shape factor

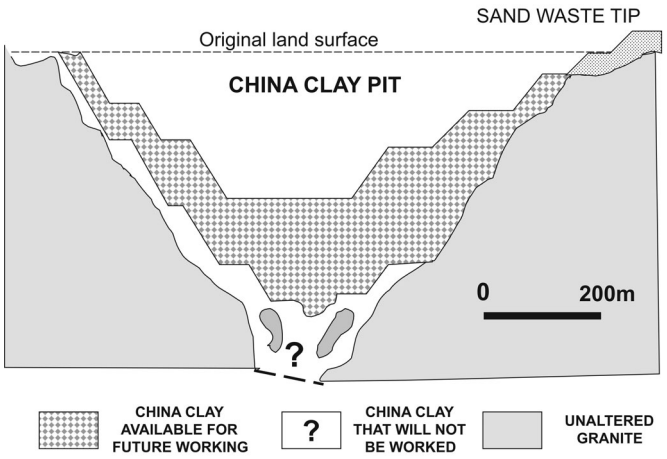

Figure 4. *Typical cross section across a china clay pit in the St. Austell Granite.*

(called a factor as aspect ratio is not actually measured). The method is known as PANACEA (particle assessment *(by)* natural alignment *(and)* conductivity effect analysis). Measurements of shape factor are made online and help to control the process. Traditionally, aspect ratio was measured by the TEM shadowing technique which was a very lengthy process relying on the particle thickness being proportional to the shadow length - the thinner the platelet of kaolin the narrower the shadow. Platy kaolin is important in certain types of paper such as light weight coated and supercalendered.

Imerys produces three types of calcined clay. Molochite, the calcined clay for refractories (used in investment casting and kiln furniture) uses processed kaolin pressed into bricks which is then passed through a tunnel drier at 240°C for 32 hours. This is followed by passing through a tunnel calciner at 1500°C for 48 hours. The resultant material is very hard, consisting of mullite and cristobalite, and has to be crushed and separated into varying sizes. The Herreschoff Kiln is used to produce calcined clays mainly for performance minerals (paint, rubber and plastics). Here a carefully selected kaolin is passed through the Herroschoff (a multi-hearth kiln) at 800-1100°C for 30 minutes. There is some fusion so the calcined clay is milled. The calcined clay produced is known as Polestar (mainly for paint and rubber) and Polarite, a chemically treated calcined clay for use in plastics (particularly for high voltage cable plastic covering). A new product introduced in 2001 is "Opacilite" used as an extender in paint. The clay is flash calcined at 850°C and forms tiny sealed voids within the kaolin which improves opacity in paint.

In 2001, the sales of kaolin from Imerys was 2.2 Mt destined mainly for the paper market (75%), performance minerals – paint, rubber and plastics (12%) and ceramics (13%). Whilst Devon and Cornwall produce a wide range of products for paper, based on the ability to offer a range of delaminated engineered clays, the competition from the Amazon Basin for the higher brightness coating pigments resulted in Imerys deciding in 2002 to switch 0.15 Mt of such products to RCC (Rio Capim Caulim). The range of coating pigments that Imerys offer from its operations in the USA, Brazil and the UK are shown in Table 4: high brightness engineered pigments from the UK such as Suprastar and Supraprint will be replaced by engineered pigments from Brazil such as Capim DG and GP.

Plant	Capacity (tpa)	Sales (2001)	Markets
Greensplat	100,000	80,000	Mainly paper and some ceramic grades
Trelavour	150,000	120,000	Mainly ceramics
Total	250,000	200,000	

Table 5*. Production capacities and sales of Goonvean for 2001.*

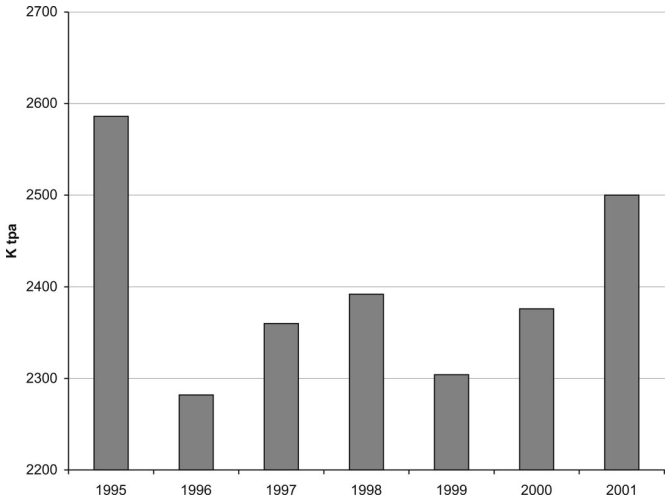

Figure 5. *Kaolin production from Devon and Cornwall for the period 1995 to 2001 (K tpa).*

Pit	Area (Ha)	Kaolin products (tpa)	Quality	Comments
Headon	177	100,000 tpa 10-12% Yield	White firing, high brightness kaolin from matrix	105,000 tpa of sand & aggregates produced
Shaugh	140	40,000 tpa	Strong, more plastic clay, not so bright as Headon Pit Plant	130,000 tpa of sand & aggregate. 5 km pipeline to Headon

Table 6. *Production of kaolin from WBB Minerals china clay pits on Dartmoor Granite*

Imerys in Devon and Cornwall will continue to be an important producer of high grade kaolin for ceramics, especially for use in porcelain, tableware and sanitary-ware, based on the low iron and titanium levels (for porcelain and tableware) and good casting properties (for sanitary-ware). Investment by Imerys in its operations in Devon and Cornwall continues with over £40 M (US$60) being spent in 2001/2 on completion of a flash-calciner for "Opacilite" (a new extender for paint), streamlining refining facilities with pipework replacement and upgrading centrifuges. Pit development has taken place with new schemes for Blackpool and Wheal Martyn and expanding the Littlejohns and Melbur pits. Finally the building and commissioning of a new fluid bed dryer for ceramics products has been completed replacing the old rotary dryer. To streamline the mining operations Goonbarrow/Rocks pits will continue for another 2-3 year with Gunheath Pit closed due to high costs of waste removal (mainly hard waste rock). Stannon Pit on Bodmin Moor, whilst having good reserves left, has closed with centralisation of mining in the St. Austell area. The Rocks Dryer will gradually be phased out and in future drying will be concentrated in Par Harbour as it is adjacent to the ports of Par and, by a private road, to Fowey.

GOONVEAN

Goonvean was established in 1931 as Goonvean & Rostowrack and by the acquisition of the operations of Redland plc in 1995 doubled the size of its operations. Goonvean is now the only one of the three operating companies in south-west England that is British owned. Goonvean has four operating china clay pits – Rostowrack, Goonvean, Wheal Prosper and Greensplat. They also own Trelavour Down which at the present time is not working. Bodelva Pit was sold and is now occupied by the Eden Project.

Goonvean has two processing plants at Greensplat and Trelavour and details are shown in Table 5. Sales to the paper

% Utilisation of pigment in paper	1980	2000
Kaolin	87	40
Ground calcium carbonate	9	33
Precipitated calcium carbonate	<1	14
Other pigments	4	13

Table 7. *Utilisation of pigments in paper showing significant replacement of kaolin by GCC (ground calcium carbonate) and PCC (precipitated calcium carbonate) and others (includes talc) from 1980 to 2000.*

market account for 55% of the volume and 45% of the value. Ceramics, with 40% of the sales volume, accounts for 45% of the sales value. Other markets accounting for 5% of the volume and 10% of the sales value include paint, rubber and plastics. Annual turnover for 2001 was £12 M (Hart, pers. comm., 2001). Over the last two years Goonvean has invested £7.5 M in new plant including wet storage, screens, bleaching circuits and a new thermal dryer. 90% of all products are exported with 10% being for the UK market. Exports are 60% to Europe (Scandinavia being

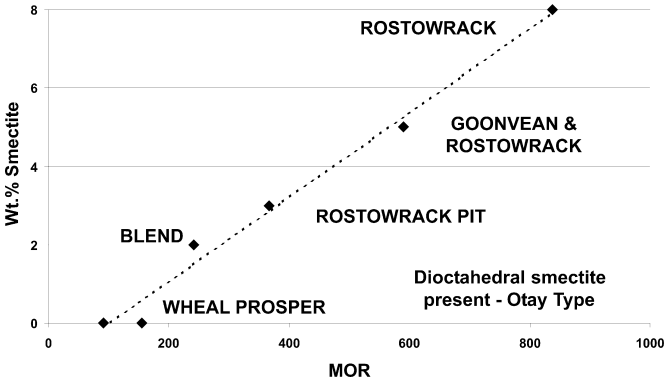

Figure 6. *The presence of smectite (montmorillonite) in the kaolin increases the strength (modulus of rupture, MOR).*

an important market) and 30% to non-European countries. Goonvean also act as agents for other kaolin companies including CADAM, PPSA (Brazil) and Burgess (USA).

Goonvean have developed new products for high quality ceramics over the past four years. A new product called *Diamond Star* is now being sold for use in high quality tableware and porcelain and competing with Imerys' Super Standard Porcelain (*SSP*) and *Premium* (from NZCC – New Zealand China Clay). *Diamond Star* has low iron (0.42 wt.% as Fe_2O_3) and titanium (0.08 wt.% TiO_2) which gives rise to excellent fired whiteness and translucency in tableware (in both oxidative and reductive firing conditions). The clay has good strength and plasticity and a low deflocculant demand. It has also been developed for use in iso-static pressing as well as in traditional plastic bodies. Whilst the clay has only been on the market for 2 years it has achieved sales of 2,500 tpa.

The clays for ceramic products only come from Rostowrack, Goonvean and Wheal Prosper pits. The Rostowrack and Goonvean pits are characterised by the presence of smectite, mainly montmorillonite. Montmorillonite, having such a large surface area, can increase the strength of kaolin if present in small amounts. The strength of a kaolin, measured as the modulus of rupture or by the methylene blue index, is an important property for use in porcelain bodies. A detailed study (Scott *et al.*, 1996) shows the montmorillonite in the Goonvean pits is a montmorillonite of the Otay type. The relationship between increasing modulus of rupture with higher smectite levels is shown in Figure 6 from the three pits. For sanitary-ware, the important parameters are casting concentration and casting rate. The presence of montmorillonite improves the strength but generally decreases the casting properties. Whilst, some sanitary ware slips require some strength a range of products with varying

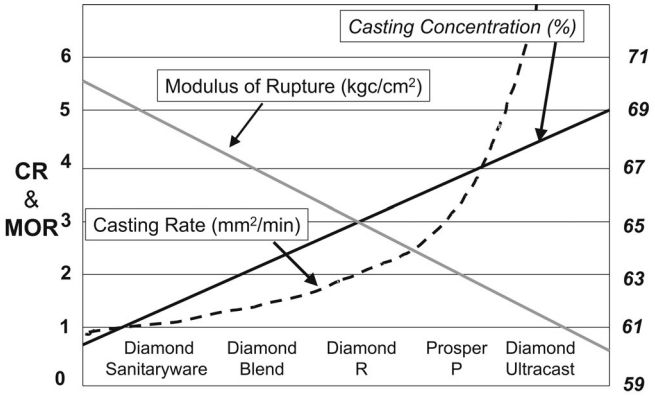

Figure 7. *The variations in modulus of rupture (MOR), casting rate (CR) and casting concentration of Goonvean ceramic clays.*

casting properties and strength can be produced by controlling the different feed clays. The relationship between casting rate, casting concentration and modulus of rupture for the range of Goonvean sanitary-ware clays is shown in Figure 7.

Paper clays are produced at the Greensplat plant. Here the process utilises cyclones to reject the coarse kaolin stacks which are then delaminated to give high aspect ratio kaolins for light weight coated and rotogravure papers. Goonvean utilise their own type of sand mill to delaminate the stacks.

WBB Minerals

WBB Minerals is now part of the Belgium Sibelco Group, a major industrial minerals company. WBB's major activity in the UK is the production of ball clay from deposits in Devon and Dorset. Kaolin production is confined to the Dartmoor Granite at Lee Moor where they have two pits, Shaugh and Headon and details of these operations are shown in Table 6.

The plant at Headon has a capacity of 150,000 tpa with sales of 140,000 tpa in 2001. Processing is wet mining by monitors, de-sanding by bucket wheels, and then the traditional hydrocyloning, thickening, blending, bleaching, filter pressing, noodling and drying prior to dispatch. In 2002 an Eriez magnet was installed to improve the brightness of the clay by reducing the iron levels. Of the 140,000 tpa of sales, 80% are exported with 20% for the UK market. The markets served are paper (20%), ceramics (70%) and others – paint, rubber, plastics, marine paints and fertilizers (10%). The main paper customer is UPM-Kymmene in Finland who buy a filler clay. For exports, the main port is Plymouth with Teignmouth also being used as ball clay is also exported from here.

Competition

The main market for kaolin is paper and 75% of the sales from Devon and Cornwall are destined for this sector. Over the last twenty years the competition for kaolin produced from Devon and Cornwall has come from other deposits of kaolin in other countries and from other minerals such as ground calcium carbonate, precipitated calcium carbonate and talc.

Kaolin competes with ground and precipitated calcium carbonate and talc in the paper, paint and plastics industries. In 1980, approximately 87% of the pigment use in paper was kaolin and this has reduced to 40% by 2000. Ground calcium carbonate which was 9% of the market in 1980 has increased its share to 33%, and precipitated calcium carbonate, virtually unused in 1980, now has a 14% market share (Table 7). This trend toward calcium carbonate has mainly been as a result of an alkaline paper-making system being introduced and replacing an acid system, and also because of the requirements of higher brightness pigments for wood-free pulp. Kaolin brightness for coating grades is between 86-90 ISO, whilst ground calcium carbonate and precipitated calcium carbonate can achieve >95 ISO brightness.

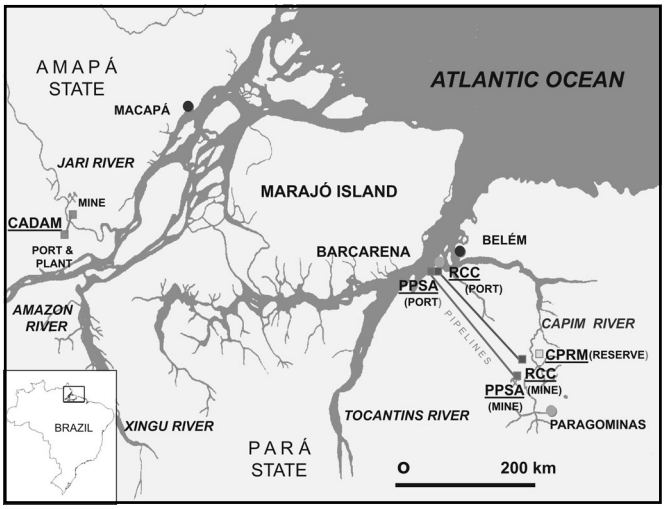

Figure 8. *Location of mines and plants of the Brazilian Amazon Basin kaolin producers – CADAM, PPSA and RCC.*

Kaolin has a platy morphology that is still required for a large number of paper applications, particularly in light-weight coated papers. The trend in recent years has been for a combination of different minerals being used in the same coating formulation. Ground calcium carbonate can be mixed with kaolin, ground calcium carbonate with precipitated calcium carbonate and more recently talc with ground calcium carbonate to obtain improved performance. If a choice is made between kaolin and ground calcium carbonate for coating, the papermaker considers the colour solids (makedown solids of pigment and chemicals prior to applying coating to paper - the higher the solids the less drying of paper to be carried out), paper brightness, paper opacity, fibre coverage, paper gloss and print gloss. For high brightness paper, ground calcium carbonate is utilised but for fibre coverage, paper gloss and print gloss the platy nature of kaolin is preferable. Kaolin is widely used in paint as an extender and the calcined grades give higher opacity than a hydrous type. There are regional trends, with the US still relying dominantly on kaolin for coating, followed by precipitated calcium carbonate and ground calcium carbonate. In Europe and Asia the trend has been more towards the use of ground calcium carbonate, no doubt due to the proximity of high-quality marble deposits in such places as Carrara (Italy) and Ipoh (Malaysia).

The world kaolin market of high quality beneficiated kaolin is estimated at 24.4 Mt for 2001 (Wilson, 2002). Leading producing kaolin companies of the world are shown in Table 8 with Imerys accounting for 25%. For leading kaolin producing countries, USA, mainly based on the sedimentary deposits of Georgia account for 36%, United Kingdom 10%, Brazil 9% and other countries 45%. Brazil has shown the most significant growth and can expect to overtake the United Kingdom in the near future. Large reserves of high quality coating kaolin have been discovered in the Amazon Basin and over the last 20 years have been developed. These deposits are all sedimentary in origin and are found widespread throughout parts of the Amazon Basin. The main operations in the Amazon Basin are CADAM (jointly owned by Mitsui and CVRD - Companhia Vale de Rio Doce is the largest exporter of iron in the world), PPSA (Para Pigmentos SA - 77.5% owned by CVRD and Mitsubishi Corporation) and RCC (Rio Capim Caulim - 99.86% owned by Imerys with 0.14% by Sumitomo Corporation). These three companies currently have an installed capacity of 2.0 Mtpa split between CADAM (0.8 Mt), PPSA (0.6 Mt) and RCC (0.6 Mt). The location of the deposits and plants of these companies is shown in Figure 8. Sales in 2001 brought in revenue of US$ 200 M. Proven reserves of kaolin are put at > 500 Mt with CADAM having 270 Mt of ultra-fine clay (98 wt.% $<2\,\mu$m), PPSA 110 Mt of platy clay at 82-85 wt.% $<2\,\mu$m (excluding other reserves that CVRD control in the same region) and RCC with 120 Mt of platy type kaolin at 78-94 wt.% $<2\,\mu$m. Future expansions based on these large high quality reserves are planned with CADAM aiming to produce 1.0 Mtpa by 2007, with PPSA 1 Mtpa and RCC 0.85 Mtpa by mid-2003.

Conclusions

In the face of increasing competition from other kaolin deposits in the world, particularly Brazil, and the use of other pigments such as ground calcium carbonate and precipitated calcium carbonate in paper, the china clay industry of Devon and Cornwall has been under attack. However, with the high level technological knowledge of both the deposits and customers' needs the industry has reacted well over the last decade with a range of new products based on different processing routes to maintain a strong position. All three companies, Imerys, WBB Minerals and Goonvean, have invested significant sums in new plant and equipment to streamline their operations and backed up by technical support to the customers have more than held their own in a very competitive environment. The remaining high quality resources of kaolin backed up by new processing technology, good logistics and markets will ensure that the china clay industry of Devon and Cornwall will be a significant force for at least the next 50 years.

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Company	Headquarters	Main producing countries	% of World's kaolin market
Imerys	France	Australia Brazil U.K. New Zealand U.S.A.	25%
Engelhard	U.S.A.	U.S.A.	8%
Huber	U.S.A.	U.S.A.	6%
Thiele	U.S.A.	U.S.A.	5%
AKW	Germany	Germany	4%
CADAM	Brazil	Brazil	4%
PPSA	Brazil	Brazil	2%
Others	various	various	46%

Table 8. *The leading kaolin producing companies of the world with a market of 24.4 Mt for 2001.*

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