Communities and Local Government

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Mineral Planning Factsheet

Kaolin

*This factsheet provides an overview of **kaolin** supply in the UK. It forms part of a series on economically important minerals that are extracted in Britain and is primarily intended to inform the land use planning process. It is not a statement of planning policy or guidance; nor does it imply Government approval of any existing or potential planning application in the UK administration. September 2009*

China clay or **kaolin** is a commercial clay composed principally of the hydrated aluminosilicate clay mineral **kaolinite**. The term **kaolin** is used here. The commercial value of kaolin is based on the mineral's whiteness and its fine, but controllable, particle size which may be optimised during processing. Particle size affects fluidity, strength, plasticity, colour, abrasiveness and ease of dispersion. Other important properties include its flat particle shape, which increases opacity or hiding power, its soft and non-abrasive texture, due to the absence of coarser impurities, and its chemical inertness. These key properties distinguish kaolin from the other kaolinitic clays produced in Britain, such as ball clay and fireclay (see Factsheets on **Ball clay** and **Fireclay**). The kaolinite content of processed grades of kaolin varies, but is generally in the range 75 to 94%. Associated minerals may have a considerable influence on the suitability of the clay for a particular application. Kaolin from different deposits in Britain, and from around the world, have markedly different properties.

Hydraulic mining of kaolinised granite.

Markets

Kaolin has a range of industrial applications, which are grouped in three main market areas; paper; ceramics; and other speciality uses. Demand is dominated by the paper industry, which accounts for just under 50% of total sales from the UK. Kaolin performs two quite separate functions in the manufacture of paper. As a filler, it is incorporated into the paper sheet (web), both reducing its cost and improving its printing characteristics. Of particular importance is high-quality paper for colour printing for advertising and promotional literature, although other paper types are also important. Lightweight coated papers can contain up to 35 to 40% kaolin both as a filler and coating medium. It is also used as a coating pigment, enhancing the surface properties of the paper. Following major changes in the pattern of production in 2007, UK output of kaolin for the paper industry is solely concentrated on filler grades.

The ceramics industry is the second most important sector, accounting for about 30% of total sales. Main markets are in Europe, Middle East and Asia. Kaolin is used in the manufacture of whiteware ceramics where its main function is to confer whiteness to the ceramic body. Its major uses are in vitreous-china sanitaryware, tableware (earthenware, bone china and porcelain), wall tiles, electrical porcelain and glazes. Fired brightness, strength and (in sanitaryware) rheological (flow) properties are the key parameters for ceramic whiteware. Properties such as plasticity that are desirable in ceramic manufacture may be detrimental in paper-coating applications. Kaolin is also used in refractories, where it is valued for its high alumina content.

Speciality applications use kaolin as fillers in paint, rubber, plastics and adhesives and sealants, and pharmaceuticals. Other uses include the manufacture of animal feed, white cement and glass fibre.

Supply

The UK is the world's third largest producer and exporter of kaolin after the USA and Brazil.

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Total sales were 1.36 million dry tonnes (moisture free basis) in 2008, a significant decline on peak sales of 2.78 million dry tonnes in 1988. Since then the industry has faced difficult market conditions as a result of increasing competition in Western European paper markets from imports of kaolin from the Amazon Basin in Brazil which is now the major supplier of coating kaolins into European markets. Alternative white pigments, in particular fine ground calcium carbonates, also compete with kaolin.

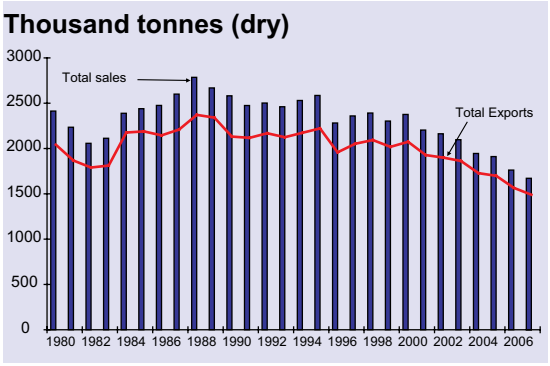

Figure 1 UK total and export sales of kaolin, 1980–2007. *Source: UK Minerals Yearbook 2008, BGS.*

Kaolin production is confined to the granites of south-west England, principally the western and central parts of the St Austell Granite in Cornwall and the south-western margin of the Dartmoor Granite in Devon. The St Austell Granite is the most important, accounting for about 88% of total sales.

Trade

For many years, kaolin has been Britain's most important mineral export after hydrocarbons. In 2008 some 88% of total were exported around the world (1.19 million), although the largest single market is Europe. There are no significant imports.

Consumption

UK consumption of kaolin is relatively small in comparison to total sales. Home sales have declined from some 450 000 tonnes in 1990 to 167 000 tonnes in 2008 (see Figure 1). The comparatively small home market is due to an absence of a significant domestic papermaking industry and the weakness of the domestic whiteware ceramics industry in the face of increasing overseas competition.

Value

The kaolin resources of south-west England are a significant economic asset. The total annual value of UK kaolin sales is placed at some £155 million. In Devon and Cornwall the china clay industry makes a major contribution to the local economy. Some 1350 people are directly employed by the industry and it is the largest manufacturing employer in Cornwall. Although domestic sales are modest in comparison to exports they do help to underpin the UK whiteware ceramics industry.

Structure of the industry

There are three kaolin producers in the UK: Imerys Minerals Ltd, Goonvean Ltd; and Sibelco UK Ltd. They are members of the trade association known as the Kaolin and Ball Clay Association UK. Imerys Minerals Ltd is by far the largest producer accounting for over 77% of the total output with operations in both Cornwall and Devon. The company is a subsidiary of the IMERYS Group of France, the world's largest kaolin producer with major operations in the USA, the Amazon Basin and elsewhere in the world, and with about 25% of the world market. Goonvean is a privately-owned company with five operations all within the St Austell Granite. Sibelco UK Ltd has operations only in Devon and is owned by SCR Sibelco of Belgium

Resources

Kaolin resources in Britain are confined to the granites of south-west England and the deposits are world class in terms of size and quality. All the main granite intrusions have been worked to some extent in the past, but production has historically been based on the central and western parts of the St Austell Granite and the south-western margin of the

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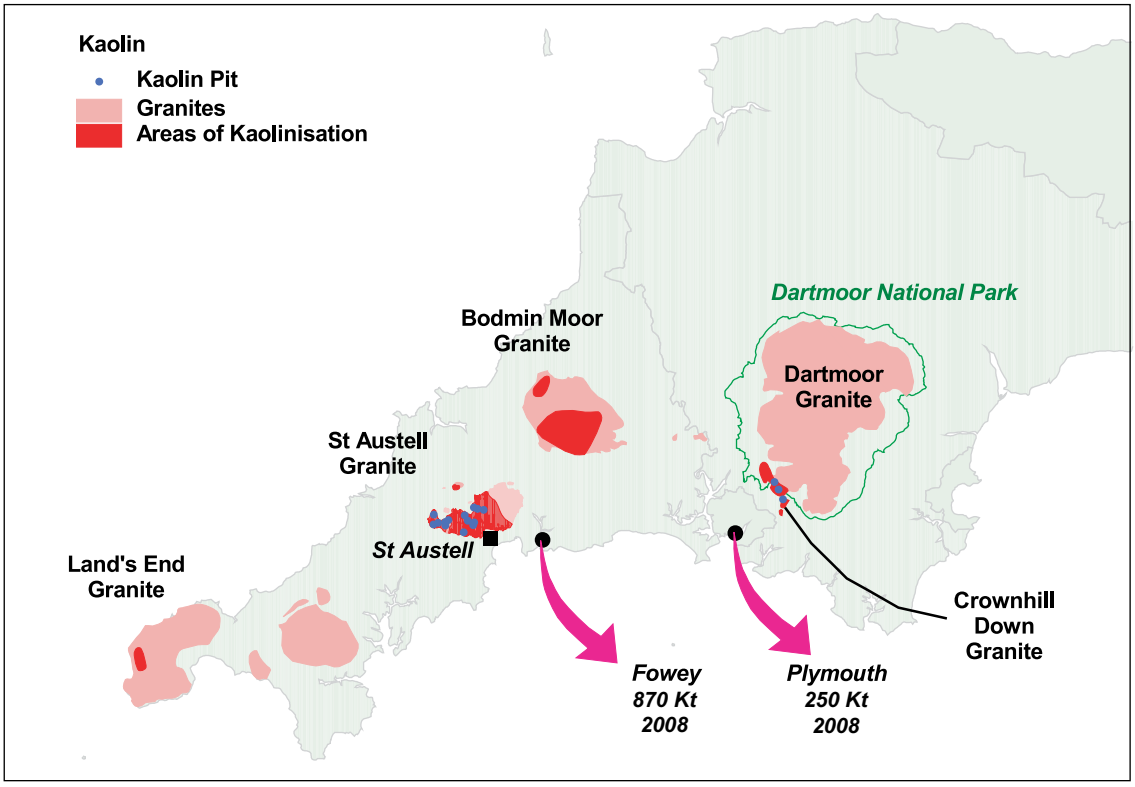

Figure 2 Granite outcrops and areas of kaolinisation, south-west England.

Dartmoor Granite (Figure 2). Minor output from the Bodmin Moor Granite ceased in 2001. The St Austell Granite is by far the most important source and has the capability (unique in the world) to produce a wide variety of high quality kaolin grades. It will continue to be the principal UK source in the future.

The UK kaolin deposits are of primary origin and were formed by the in situ alteration of the feldspar (mainly plagioclase) component of the granites. The kaolinisation process involved the decomposition of feldspar by hydrothermal fluids and surface weathering to form kaolinite and mica. Most other minerals are largely unchanged by this process. The clay mineral smectite may sometimes form as an intermediate product between feldspar and kaolinite. Its presence, even in very small amounts, is commercially important as it has a detrimental effect on the performance of some clays, although it increases the strength of ceramic clays, which is beneficial in some ceramic applications.

Zones of commercial kaolinisation are generally related to permeable fracture and vein systems through which the kaolinising fluids circulated. The kaolinised zones are funnel or trough-like in form narrowing downwards (Figure 3) but merging of funnels gives more extensive zones of kaolinisation.

Kaolinisation may extend to depths of over 250 m, although 100 m is more typical, a fact that has important practical implications for kaolin production since opportunities for progressive backfilling of pits is confined by the need to maintain access to reserves.

Kaolinised zones contain a wide spectrum of rock types from hard, unaltered granite ('stent') through to a soft kaolinised 'clay matrix' consisting of a friable aggregate composed principally of quartz, mica, unaltered feldspar, tourmaline and fine-grained kaolinite which mainly occurs in the < 20 µm fraction. The kaolinite content of the clay matrix is vari-

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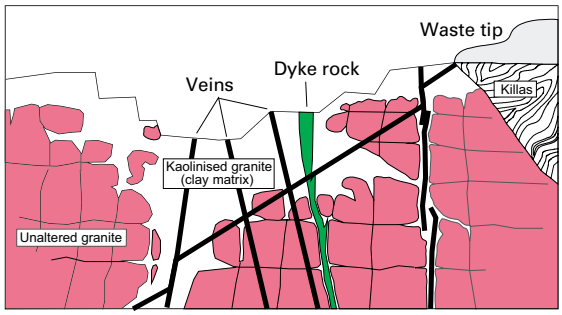

Figure 3 Cross section of a kaolin deposit.

able but typically in the range 10–25%. Overall kaolin recovery is around 15%.

The St Austell Granite covers an area of about 93 km^2 and is extensively kaolinised in its central and western parts, over an area of about 63 km^2. The western part of the St Austell Granite has traditionally supplied ceramic clays. The remaining central and eastern parts tend to produce all other grades.

Kaolin is also produced on the extreme south-western edge of the Dartmoor Granite (Lee Moor) and on the adjacent, but separate, Crownhill Down Granite. Kaolinisation has also been intense. There is a higher proportion of sand and less rock than in the St Austell Granite. The kaolin also has lower iron and potash contents than in Cornwall and a larger proportion of sales are used in ceramics and speciality applications. There is also a significant output of calcined kaolin for which the clays are well suited. This involves heating the clay at different temperatures to produce clays with enhanced brightness.

Sibelco is now the only producer extracting kaolin at Lee Moor. A joint working venture has been agreed by Sibelco and Imerys to restart operations on the Crownhill Down Granite and development commenced at Hemerdon during 2008. Although kaolin at the nearby site at Smallhanger is not currently worked, its reserves are of long term importance to the industry.

Reserves

A figure for total permitted reserves of kaolin is not available for commercial reasons. However, sufficient proved reserves of kaolin exist in and around existing pits both in Cornwall and Devon to sustain current rates of production, using existing technology, for at least 50 years. Reserves thus exceed the life of current planning consents. In detail the figures differ by grade, area and company. The projected life of reserves in Devon exceeds those in Cornwall.

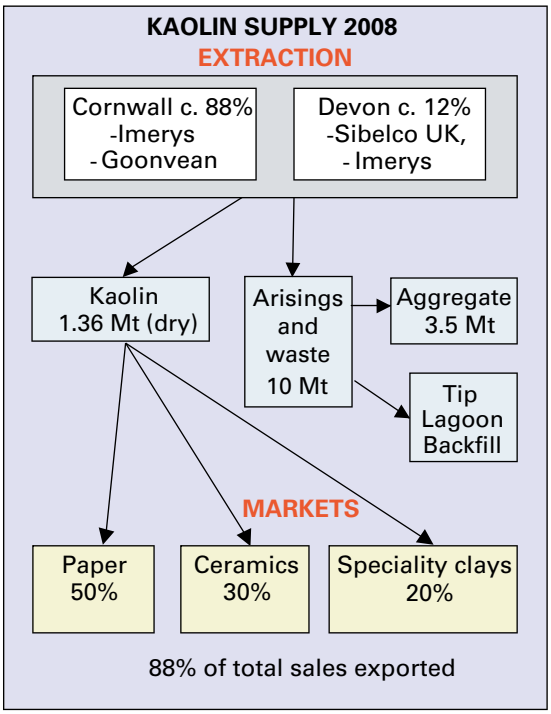

Figure 4 Kaolin supply chain, 2008.

Relationship to environmental designations

Kaolinisation on the south-western part of the Dartmoor Granite is adjacent to and extends into the Dartmoor National Park. In 2001, the two companies working in the area announced their intention to relinquish their planning permissions within the National Park because of the impact that these workings would have on a sensitive area.

There are several SSSIs (mainly geological) located within the operational area in Cornwall. Goss and Tregoss Moor Special Area of Conservation is located just to the north-east of the main kaolin extraction area.

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Extraction and processing

The extraction and processing of kaolin in south-west England involves the production of large quantities of arisings much of which has previously been discarded as waste. The arisings produced are of two main types: cCoarse material comprising sand (mainly quartz); and rock, otherwise known as 'stent'. Much of this material is processed and sold as aggregate (see 'By-products') or stockpiled. Lower quality material is disposed of in large tips or, increasingly, backfilled into pit voids, where sterilisation of unworked reserves will not result. A fine slurry called mica residue is disposed of in large lagoons and abandoned kaolin pits. In the lagoon the mica settles out and the water is pumped off for reuse. Some older mica lagoons have been reworked to recover coarser kaolinite formerly lost in processing.

Kaolin extraction has traditionally been by hydraulic mining in which high-pressure jets of water are used to disaggregate the weak, kaolinised granite and disperse the kaolinite particles, together with the other components of the granite, into a slurry. Ripping, drilling and blasting of the granite are also used to improve yields and unkaolinised material is removed for tipping, although some is processed into aggregate. More recently, 'dry' mining has been introduced. This allows more selective extraction and improved yields. The kaolinised granite is extracted by shovel and truck and is transported to a primary screening process to remove large oversize material. The undersize is disaggregated by high-pressure jets of water for subsequent processing in the conventional way. 45% of Imerys' output is now produced using this methodology.

Separation of the fine kaolinite particles from the coarser waste, consisting mainly of quartz, unaltered feldspar and mica, is by a series of wet refining techniques. Additional techniques are used to improve the brightness (whiteness) and particle size of specific grades of clay. These include blending, fine grinding, chemical reductive bleaching and/or the removal of iron-bearing impurities using superconducting magnets. Some clays are also calcined at specific temperatures to give different products.

Finally the clay is dried to a powder or pellets, or supplied in slurry form as a suspension of clay in water.

The ultimate disposal of the waste products has been a major problem because of the large areas that are required and the visual impact. However, about 40 abandoned pits have been backfilled where this has not affected reserves or the requirements for water holding areas. As the surface extent of workings reach their practical limits surface tipping is giving way in favour of backfilling.

The kaolin supply chain is summarised in Figure 4.

By-products

Each tonne of marketable kaolin recovered typically produces up to 9 tonnes of other material, comprising approximately 4 tonnes of sand, 3 tonnes of rock (stent), 1 tonne of overburden and 1 tonne of micaceous residues. Total industry arisings are some 10 million tonnes a year, of which about 4 million tonnes is sand. The total industry 'stockpile' has been estimated at over 600 million tonnes, although much of this is now in tips that have been engineered and landscaped.

In 2008 3.5 Mt of aggregate derived from kaolin working were sold. These sales are mainly derived from arisings currently produced, although some stockpiles were reworked.

Alternatives/recycling

Alternative white minerals to kaolin are used as fillers in paper, paint and plastics and as coating pigments in paper. The most important is fine ground calcium carbonate (chalk, limestone and marble), which is widely available, but talc is also used in some countries. Precipitated calcium carbonate is also finding increased use. The former dominant position of kaolin in the paper industry has been eroded by the change from acid to alkaline and neutral papermaking systems, which allow the use of calcium carbonate as a filler. The introduction of finely ground calcium carbonates also allowed their use in paper coating.

Consequently, calcium carbonate now has some 60% of the paper market, although the growth in the total size of the market has meant that demand for kaolin has remained static. However, this substitution may now have reached its limit because the platey structure of kaolin remains a desirable property for many applications.

Recycling of paper allows some of the mineral components to be recovered.

Effects of economic instruments

Sales of sand and crushed rock derived from kaolin extraction and processing are exempt from the Aggregates Levy, which now stands at £1.95/tonne. This has given a further stimulus to their increased usage and some 3.5 million tonnes were sold in 2008, almost all in Cornwall where it accounts for about 80% of aggregate sales. It is estimated that about 0.3 million tonnes of kaolin-derived aggregate was 'exported' beyond Devon and Cornwall in 2008. Major increase in the use of this material outside the local area is likely to require a significant increase in the Levy on primary aggregates.

Kaolin production is subject to the Climate Change Levy (CCL), which is primarily aimed at reducing carbon dioxide emissions, but via its proxy — energy use. Kaolin production is energy intensive and thus was siginificantly affected by the Levy. A rebate was agreed in 2006 which industry considers to partially offset any disadvantage against international competition.

Transport

As the bulk of production is exported through the ports of Fowey and Plymouth, most shipments are by sea. Shipments from the port of Par ceased in 2007.Overall some 77% is transported by sea, 13% by rail and 10% by road.

Planning issues

- **By-products** — kaolin extraction and processing creates very large quantities of sand and rock arisings as a by-product
- **Economic viability of arisings as an aggregate resource** — the rate at which the Aggregates Levy is set on primary aggregates is fundamental in determining the level of usage of kaolin-derived aggregate beyond Cornwall.
- **Transport** — arisings from kaolin extraction and processing are a major aggregate resource, significant extension of the use of these materials beyond the local area remains problematic. This aggregate resource is relatively remote from major markets elsewhere in England and freight costs are significant.
- **Restoration of tips and pits** — the geology of kaolin deposits in south west England means that backfilling can result in sterilisation of reserves at depth and some pits have considerable longevity. This can sterilise void space that might otherwise be used for backfill. However, an increasing amount of material is now backfilled as pits are exhausted. New permissions for tipping provide opportunities to tackle the legacy of degraded landscapes, past environmental damage and lack of alternate land uses. Significant areas are being restored to heathland and woodland.
- **Concentration of workings and their cumulative impact** on the landscape is linked to the problem of arisings and waste. In Cornwall, active and legacy workings, together with associated tips, are concentrated in a relatively small area (less than 90 km^2). This has had a major intrusive effect on the St Austell area. The workings in Devon are largely located on high ground, close to the border with the Dartmoor National Park, with consequent issues over visual impact and effect on sensitive moorland ecology and archaeology. In Cornwall, kaolin working continues to have an impact on species and habitats. Sites of county importance for wildlife or geology have been threatened by tipping, although tips and workings do provide habitats for internationally-significant rare plants and major opportunities for recreation of habitats such as heathland and woodland.

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Authorship and Acknowledgements

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Mineral Planning Factsheets for a range of other minerals produced in Britain are available for download from www.mineralsUK.com