Mineral Resources
Consultative Committee

**Mineral Dossier No 11**

# Ball Clay

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Mineral Resources Division
Institute of Geological Sciences

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*Titles in the series*

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| No 1 | Fluorspar |
| No 2 | Barium Minerals |
| No 3 | Fuller's Earth |
| No 4 | Sand and Gravel |
| No 5 | Tungsten |
| No 6 | Celestite |
| No 7 | Salt |
| No 8 | Sulphur |
| No 9 | Tin |
| No 10 | Talc |
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## Preface

The Mineral Resources Consultative Committee consists of representatives of interested Government Departments, and specialist advisers. It was set up in 1967 to keep present and future requirements for minerals under review and to identify problems associated with the availability, exploitation and use of mineral resources, both inland and offshore, having regard to competing demands on land use and other relevant factors.

Widespread and increasing interest in the mineral resources of the United Kingdom has led the Committee to undertake the collation of the factual information at present available about those minerals (other than fossil fuels) which are now being worked or which might be worked in this country. The Committee has produced a series of dossiers, each of which was circulated in draft to the relevant sectors of the minerals industry. They bring together in a convenient form, in respect of each of the minerals, data which had previously been scattered and not always readily available. These dossiers are now being published for general information.

## Acknowledgements

This dossier has been compiled with the assistance of the Department of Industry and the Department of the Environment. The help and advice given by colleagues in the Institute of Geological Sciences, in particular Dr E C Freshney of the South-Western Unit, and Mr M C Harrison and Mr D Horne of the Mineral Statistics and Economics Unit of the Mineral Resources Division, is gratefully acknowledged. An earlier version of this document was prepared by Mr I A Thomas, formerly of the Mineral Resources Division.

For their helpful comments and information thanks are due to the ball clay industry, the British Ceramic Research Association and the Nature Conservancy.

Metric units are employed throughout this document except where otherwise stated. In most cases this has necessitated the conversion of originally non-metric data. The units and conversion factors used are as follows:

| | | |
|---|---|---|
| Millimetres (mm) | = | inches x 25.4 |
| metres (m) | = | feet x 0.3048 |
| kilometres (km) | = | miles x 1.609344 |
| hectares (ha) | = | acres x 0.404686 |
| grammes (g) | = | troy ounces x 31.1035 |
| kilogrammes (kg) | = | pounds x 0.45359237 |
| tonnes (1000 kg) | = | long tons x 1.01605 |
| cubic metres ($m^3$) | = | cubic feet x 0.028317 |

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## Summary

Ball clay is a fine-grained, highly plastic, mainly kaolinitic, sedimentary clay, the higher grades of which fire to a white or near white colour in an oxidising atmosphere. They consist of varying proportions of kaolinite, clay mica and quartz, with small amounts of organic matter and other minerals, and are commercially valued because they increase the workability and dry strength of various ceramic bodies and have white or near white firing characteristics. Ball clays are used mainly in the manufacture of pottery and refractories, but have important non-ceramic applications as a filler in rubber and plastics, as an anti-caking agent in fertilisers and for pelletising animal feedstuffs. Commercial ball clay deposits are confined to three Lower Tertiary basins in south-west England; the Bovey Basin of south Devon, the Petrockstow Basin of north Devon and the area around Wareham in south-east Dorset. Similar Tertiary clays also occur in Northern Ireland but have too high an iron content to be of commercial value as ball clays.

Ball clay is produced by both opencast quarrying and underground mining, the latter method being largely confined to a limited range of high grade clays. The largest pits are 40 m deep and the largest mines, in the Bovey Basin, extend to depths of 135 m. Abandoned pits are either backfilled or fill with water and quickly revert to nature; the underground mines, which are generally inconspicuous, may cause some subsidence, although this is not usually serious. Processing consists essentially of shredding or drying and grinding, but because of the wide variation in the properties of ball clays, blending is of the utmost importance in producing uniform and consistent grades.

United Kingdom production of ball clay is recorded under the heading 'Potters' clay (including ball clay)'. Production under this heading in 1973 was 755,000 tonnes, mostly consisting of ball clay with the remainder consisting of other clays used in the manufacture of coarse pottery. Imports of ball clay are negligible, but exports, principally to Europe, amounted to 404,720 tonnes in 1973 with an f.o.b. value of £2,836,820. Trade has, therefore, a favourable effect on the balance of payments. Of the three producing areas the Bovey Basin has the greatest output, accounting for about two-thirds of total production and 70 per cent of total exports.

Three companies produce ball clay in the United Kingdom: Watts, Blake, Bearne and Company Limited, probably the largest ball clay producer in the world, ECC Ball Clays Limited (a member of the English China Clays Group) and The Wareham Ball Clay Company, a small independent producer operating in Dorset.

## Definition and mode of occurrence

'Ball clay' is a fine-grained, highly plastic, mainly kaolinitic sedimentary clay, the higher grades of which fire to a white or near white colour in an oxidising atmosphere. The name is believed to be derived from either the original method of extraction, in which the clay was cut on the floors of open pits into approximately 25 cm cubes or 'balls' weighing about 15-17 kg, or the digging implement, known as a tubal, formerly used. The term 'ball clay' has, therefore, no mineralogical significance, nor does it describe the age, properties or use of the clay. The mineralogical composition of ball clays may vary over wide limits, typical ranges being as follows: kaolinite, 15-95 per cent; quartz, 0-70 per cent and clay mica, 5-45 per cent.

In their natural state ball clays may be brown, blue, black or light grey, the darker colours being due to the presence of carbonaceous matter, of which there may be up to 16, but generally less than 1 or 2, per cent. The carbonaceous matter occurs either in lump form as lignite and is avoided during mining, or as a colloidal coating of the clay minerals, which burns out when the clay is fired. Minor constituents usually include anatase, siderite and marcasite. Marcasite, known locally as 'mundic', occurs as discrete particles, frequently replacing lignite, and is avoided during mining as it will produce specking on firing. Other minerals which may be present include chlorite, rutile, zircon, feldspar, ilmenite and tourmaline, although some authorities note that feldspar is never present and ilmenite and tourmaline are found only rarely. The kaolinite of ball clays usually has a disordered lattice and is extremely fine-grained, the plasticity of ball clays, for which they are commercially valued, probably being due to a combination of fine particle size, the presence of colloidal carbonaceous matter and, possibly, clay minerals other than kaolinite, such as montmorillonite.

The traditional market for ball clay is the pottery industry, where it is used as a body component mainly to impart plasticity and increase the strength of the unfired ware. White or near white firing ball clays, formerly referred to as *whiteware clays,* are used together with china clay, feldspar and calcined flint in the manufacture of the finer pottery known as whiteware. Siliceous ball clays, formerly referred to as *stoneware clays,* with quartz contents in excess of 30 per cent, are used in the manufacture of some stoneware. They have a lower plasticity, but because they also contain more mica, which acts as a flux, they produce satisfactory ceramic bodies without further additions, although they give buff fired colours. However, ball clay has a number of outlets where fired or unfired colour is not important and so pink and red stained ball clays can also be marketed. *Pipeclay* is an old name for ball clays, and other clays formerly used for making clay tobacco pipes. Pipeclays are recorded over much of the western half of the Hampshire-Dorset Tertiary basin including the Isle of Wight.

Ball clays occur in beds characteristically associated with a complicated sequence of lignites, lignitic clays, silty clays and sands. The beds may be lenticular in nature, as in Dorset, or exhibit rapid lateral facies variation as in the Petrockstow Basin; consequently individual beds of ball clay of a uniform quality rarely occur over extensive areas.

For a long time the ball clays of Devon and Dorset were generally considered to be 'secondary' transported clays derived from the hydrothermally kaolinised Dartmoor Granite, the finer particle size of the Dorset clays being attributable to their greater distance from the source. However kaolinite (china clay), formed by the hydrothermal alteration of feldspar, has a well-ordered lattice and relatively large crystals, whereas the kaolinite of ball clays is usually disordered and extremely fine-grained. Well-ordered kaolinite does, however, occur at higher stratigraphic horizons in the Bovey Formation and this material may have been derived from the granite. In addition, tourmaline is a common accessory mineral in the Dartmoor Granite, although it is only rarely found in sediments associated with ball clays, and ball clay deposits outside the United Kingdom are not found in association with kaolinised granites. More recently it has been proposed that the ball clays of the Petrockstow Basin (and this may also be applied to other deposits) were derived from the weathering mantle developed on Carboniferous Culm Measure shales and sandstones under the humid sub-tropical or warm temperate conditions of Lower Tertiary times.

The Dorset ball clay deposits have long been accepted as fluvial in origin, probably being deposited in temporary shallow lakes formed in the flood plain of a river flowing from the west, the increasingly saline depositonal environment to the east being indicated by an increase in the illite content of the clays. A similar fluvio-lacustrine environment for the deposition of the ball clays of the Petrockstow Basin has also been suggested, but the sediments of the Bovey Basin were until recently generally considered to be truly lacustrine. However, studies of the engineering properties of the ball clays of the Bovey Basin suggest that they are overconsolidated, indicating that they were subaerially exposed shortly after deposition, thus allowing drying of the fresh sediment. Rootlet beds at a number of horizons are indicative of vegetation growth and in agreement with sub-aerial exposure, and the presence of brecciation structures and sand channelling also suggest shallow water deposition in a fluvio-lacustrine environment. Silt infilled desiccation cracks, rootlet systems and worm burrows in the sediments of the Petrockstow Basin are also indicative of shallow water deposition. In the Bovey Basin the coarser siliceous ball clays are thought to represent the main flood plain deposits laid down at times of major flood, whereas the finer, highly kaolinitic and often carbonaceous ball clays were deposited in temporary backwater lagoons formed as the flood water subsided.

**Resources**

Commercial ball clay deposits are confined to three Tertiary basins in south-west England: the Bovey Basin of south Devon, the Petrockstow Basin in north Devon and the area around Wareham in south-east Dorset (Fig 1). Similar Tertiary clays occur in Northern Ireland but they are silty and have too high an iron content to be of commercial value as ball clays. The overall extent of the Bovey and Petrockstow Basins is well known, but the limit of ceramic grade ball clay in south-east Dorset is more difficult to define.

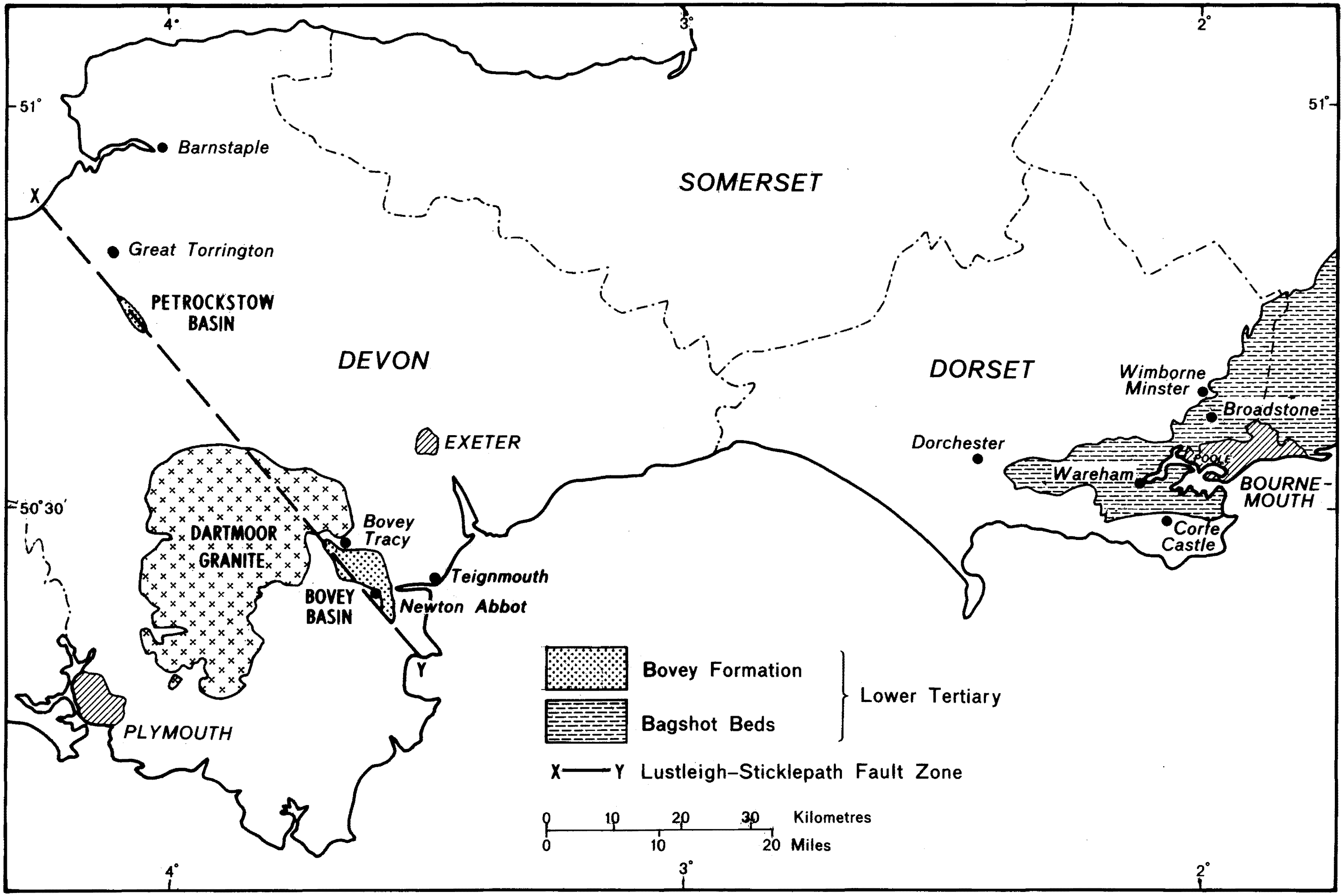


Fig 1 Location of ball clay deposits in south-west England

The *Bovey Basin* accounts for about two-thirds of the national output and an even greater proportion of total exports. The diamond shaped basin occupies an area of about 46 sq km, the north-western extremity lying to the west of Bovey Tracey and the south-eastern extremity at Newton Abbot; a small continuation south-east of the town was worked until recently but is now largely exhausted (Fig 2). The basin lies along the strike of the Lustleigh-Sticklepath fault zone and deposition of the Bovey Formation was accompanied by gradual fault subsidence, thus allowing the accumulation of a considerable thickness of sediment. The beds dip towards the centre of the basin although its western margin is defined by a major fault. The Bovey Formation is believed to be Oligocene, or perhaps Eocene, in age, covered with a superficial layer of sand and gravel of variable thickness ranging up to about 9 m. The deepest borehole in the basin was, for a long time, the Teigngrace borehole (203 m), but more recent boreholes drilled by the producing companies have reached over 300 m without penetrating the base of the Tertiary deposits. A recent geophysical survey has, however, indicated that the Bovey Formation may have a maximum thickness of some 1,200 m. The upper 400 m or so of the eastern succession is well known from workings and exploratory boreholes. It consists of a complicated sequence of sands, silt, silty clays (stoneware clays) and ball clays, with associated lignitic clays and lignites. There are over 40 workable ball clay beds ranging in thickness between 1 m and 6 m. Operations are concentrated on the eastern side of the basin over a distance of 5 km between Newton Abbot and Chudleigh Knighton. Workings in the centre and southern part of the basin are limited to Stover Park and the Ringslade-Mainbow area, respectively. The Bovey Basin has recently been mapped on behalf of the Institute of Geological Sciences under a contract with the University of Exeter.[1]

The eastern succession of the basin has been divided into three broad lithostratigraphic units. The lowest, the Abbrock Clay and Sand, consists of siliceous, non-carbonaceous ball clays and sands, these clays forming the important stoneware group of clays. The Southacre Clay and Lignite is from 30 m to at least 67 m thick and is the most important commercially; it consists mainly of carbonaceous brown clays (ball clays), the so-called whiteware clays, and thick lignite beds. The carbonaceous clays have high kaolinite contents, are white-firing and are extensively worked between Newton Abbot and Newbridge. The Southacre Clay and Lignite is overlain by grey sandy clays and coarse quartz sands of the Blatchford Sand over most of the basin west of the Teign. Brown clays associated with lignite are worked in the Blatchford Sand, for example at Stover Park. The clays, silty clays and lignite horizon of the Ringslade-Mainbow area are a lateral facies variation of the Southacre Clay and Lignite. In the northern part of the basin, south-west of Chudleigh Knighton, a sequence of silty clays, brown smooth clays, silts and sands, appears to be a distinct facies intercalated between the Abbrook Clay and Sand and the Southacre Clay and Lignite.

1 Geology of the Bovey Basin. R A Edwards. Ph.D Thesis. University of Exeter, 1970.

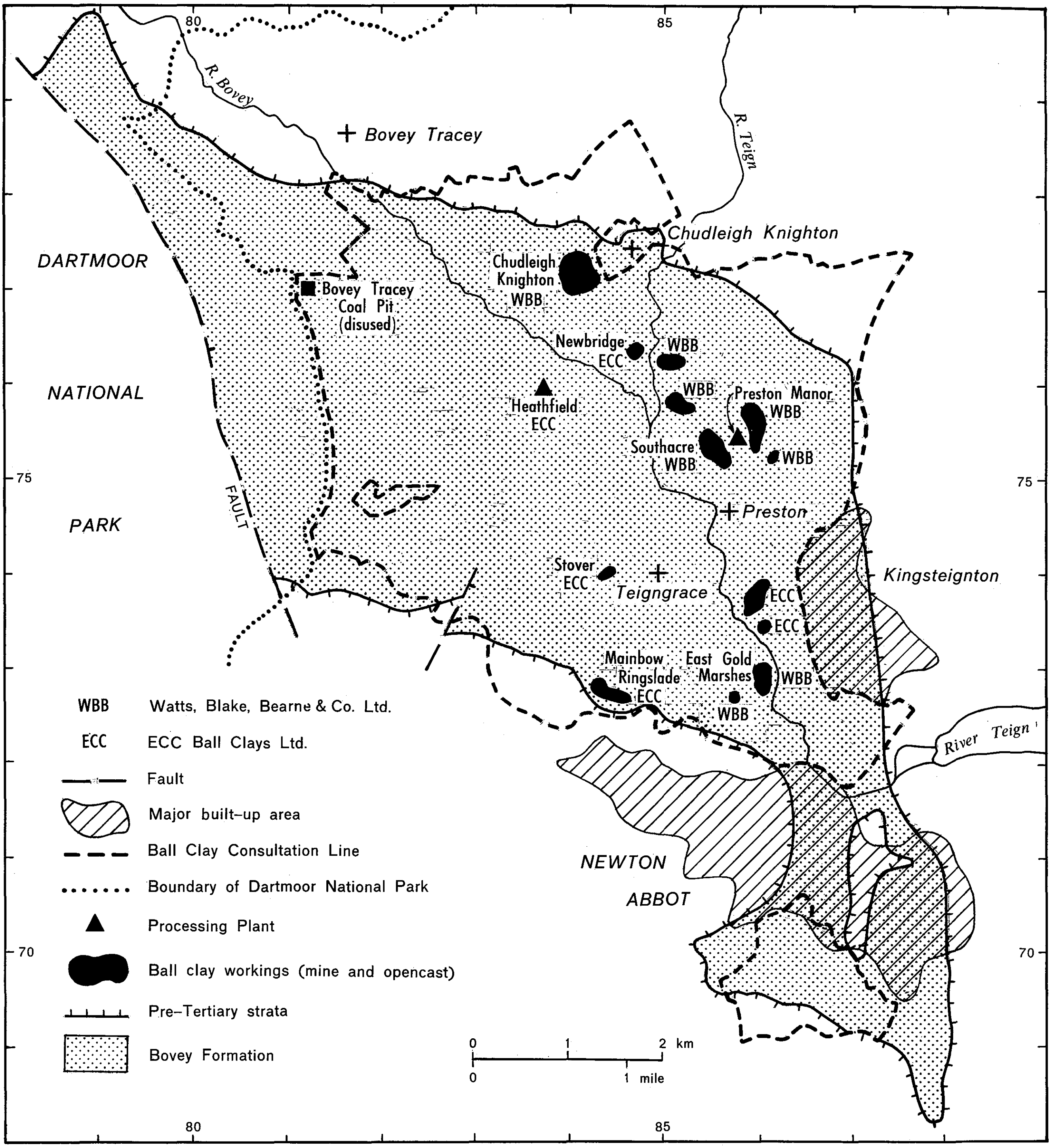


Fig 2 Geological sketch map of the Bovey Basin showing the extent of the Bovey Formation and the location of ball clay workings

The *Petrockstow Basin* of north Devon occupies an area about 800 m to 1,500 m wide by 7 km long and is bounded by two north-westerly trending faults of the Sticklepath fault zone (*see* Fig 3). The fluvio-lacustrine sediments consist of clays, silty clays, lignites, silts, sands and gravels, which are thought to be of Eocene and Oligocene age. Faulting divides the basin into a deep central trough with marginal shelf areas; an Institute of Geological Sciences' borehole drilled in 1966-67 in the centre of the trough, on the site of a small negative gravity anomaly, proved a total thickness of 661 m of Tertiary sediments, overlying Upper Carboniferous strata. Subsequently two more boreholes were drilled along the axis of the basin showing that the sediments filling the axial trough consist largely of silts, sands and gravels, with only subordinate brown clays and lignites. On the marginal shelf areas, however, particularly in the north-east and south, coarse sediments are absent and ball clays with variable silt content and some lignite are dominant, but towards the central trough the quality of the clays rapidly deteriorates. The ball clay workings are confined to these marginal deposits west of Merton, north-west of Meeth, and near Wooladon. The Petrockstow Basin is thought to be the relic of a river system which flowed northwards along the line of the Sticklepath fault zone, the coarse sediments being deposited along the central trough, with deposition of the ball clays taking place under the gentler conditions of a flood-plain environment along the margins.

The *Dorset* area ranks second in output to the Bovey Basin, accounting for perhaps 20 per cent of the total United Kingdom production: most is destined for the home market. The Lower Tertiary sediments of the western portion of the Dorset-Hampshire Basin occupy an easterly plunging syncline and lie unconformably on the Chalk attaining a thickness of about 125 m in the neighbourhood of Wareham. The ball clays, together with some inferior quality clays and small amounts of lignite, occur interbedded with coarse current-bedded sands, which make up the greater part of the Bagshot Beds (Eocene). The clay lenses, which have a maximum thickness of about 6 m, were probably deposited in the quiet backwater conditions of a flood-plain environment, although the deposits were also affected by contemporaneous erosion and channelling and the deposition of blanket current-bedded sands. The limits of ceramic grade ball clay resources in Dorset are difficult to define, but apart from three locations to the north of Wareham, ie Trigon Hill, Stokeford Heath and near Lytchett Minster, all the workings at present lie in a rectangular area bounded by Poole Harbour and the River Frome to the north and the London Clay and Cretaceous outcrops to the south and west (*see* Fig 4). Within this area there are two discontinuous east-west belts of clay, one running from East Holme to Ridge and the other, which is more extensively worked, lying immediately north of the Purbeck Hills from Povington to Rempstone, although present workings extend no further east than Norden. The structure on the southern margin of the basin, against the Purbeck monocline, is somewhat complicated by steep dips and strike faulting. Ball clay was formerly worked close to the southern shore of Poole Harbour on Newton Heath and on Wytch Heath north-east of Corfe Castle. On the northern tip of the Arne peninsula a major ball clay deposit is at present being evaluated. In the western part of the basin,

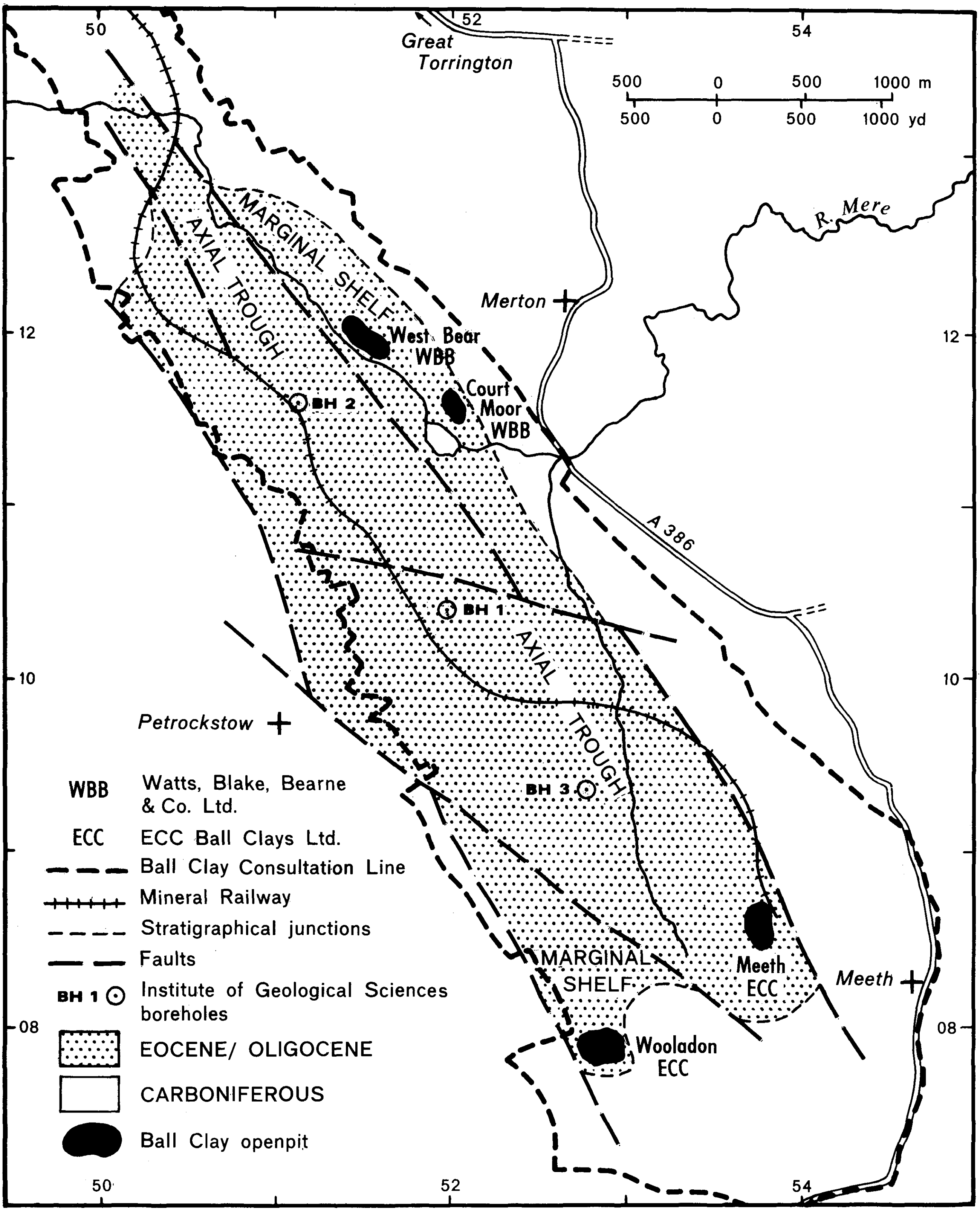


Fig 3 Geological map of the Petrockstow Basin showing the sites of existing ball clay workings. (After E C Freshney. *Proc Ussher Soc.*, 1970, Vol. 2, Pt, 3, p.181.)

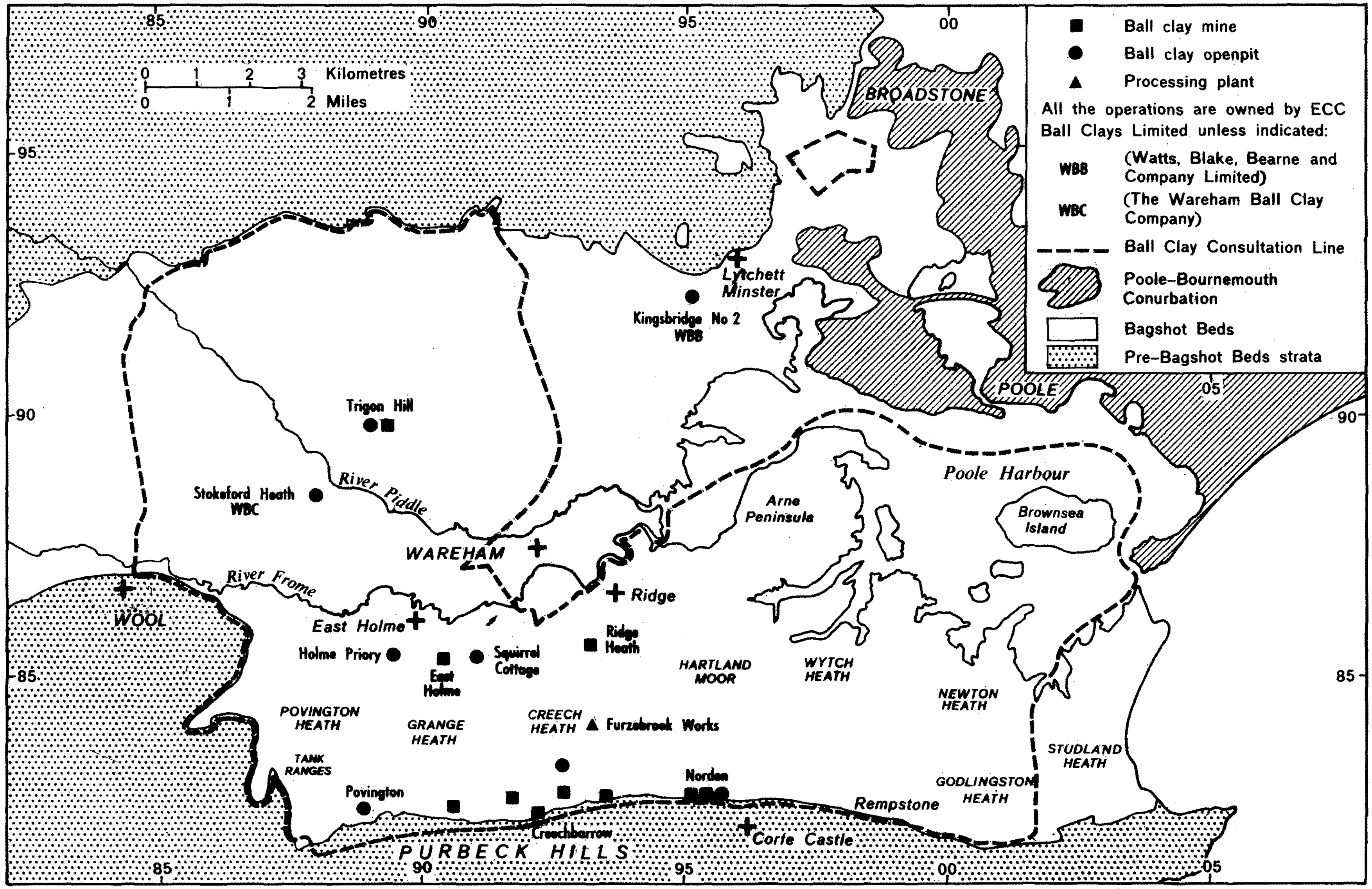


Fig 4 Geological map of south-east Dorset showing the location of ball clay workings

towards Dorchester, the Bagshot Beds become coarser. However, although ball clay has not been worked in this area and little exploratory work has been carried out, it is possible that isolated pockets may occur. To the north and east of Wareham, particularly on the north side of Poole Harbour, the ball clays are generally more siliceous, being mainly of the stoneware variety and,extensively worked for the manufacture of stoneware pipes and bricks, but all these operations have now ceased. Small amounts of ball clay are, however, quarried at Lytchett Minster and transported to south Devon for blending. Further east the clays deteriorate in quality and illite becomes the predominant clay mineral. However, former pipeclay workings are scattered over a large area of south-east Dorset and south-west Hampshire, including two localities on the Isle of Wight. They often occur at a comparable horizon to the clays now being worked, but as far as is known they are of poorer quality or thinner.

In *Northern Ireland* the Lough Neagh Clays occupy a fault-controlled basin of Oligocene/Eocene age and cover an area of about 500 sq km of which 300 sq km underlie Lough Neagh. The formation, which has a maximum known thickness of 349 m, outcrops around the southern end of Lough Neagh with its greatest extent in the south-west corner. In general, the formation consists of a thick series of pale coloured sideritic clays, sandy clays and sands, with some beds of lignitic clays and lignites. However, there are wide variations in the composition of the clays and the free quartz content may range from 3 to 65 per cent. Although the clays resemble the ball clays of Devon and Dorset, they have a higher iron content, are siltier and contain clay ironstone nodules and are unsuitable for the manufacture of whiteware. They were formerly used in the manufacture of coarse pottery but are now only worked at Ballynakelly near Coalisland and mixed with fireclay for the manufacture of brown glazed sanitary pipes. It is possible that some of these clays could have non-ceramic uses where colour is of little importance.

Elsewhere in the United Kingdom, there are a number of similar deposits of about the same geological age. For example, between the Bovey and Petrockstow Basins quartz gravels, silts and plastic clays, lying close to the Lustleigh-Sticklepath fault zone have been equated with the Bovey Formation. However these deposits are too small to be of likely commercial interest.

The maximum extent of ball clay resources in the Bovey and Petrockstow Basins is clearly defined by the limits of the Tertiary sediments in these basins, although within them individual deposits and extensions to known ball clay horizons may be found. For example, the western margin of the Bovey Basin may have ball clay potential and permission has recently been granted for exploration in this area. In the northern part of the basin, between Chudleigh Knighton pit and the disused Bovey Tracey coal pit, where lignites and carbonaceous clays of the Southacre Clay and Lignite occur, some exploratory work has been carried out and permission has been granted for future ball clay extraction. In the Petrockstow Basin, areas worthy of investigation are limited to the western and a small part of the central eastern side of the basin. Some initial drilling by the Institute of

Geological Sciences on the western side of the basin was, however, not very encouraging. The Bagshot Beds of south-east Dorset, in an area to the west of a line drawn through Bournemouth, Broadstone and Corfe Mullen, also have a considerable potential for future discoveries, although the location of isolated clay lenses, which usually have no surface expression, requires detailed borehole work.

The Lough Neagh Clays have been extensively drilled by English China Clays Limited in the area to the south-west of the lough, but it is understood that the clays were far too sideritic for general ceramic use and they fire to a biscuit colour. However, only small areas have been explored in detail and it is possible that higher quality clays may yet be found.

Elsewhere in the United Kingdom it is unlikely that there are any large undiscovered deposits except, perhaps, beneath alluvium or Tertiary lavas, for example in Northern Ireland or western Scotland. As these deposits are generally fault bounded the density contrast with the surrounding denser rocks may produce marked gravity anomalies. It is expected, therefore, that concealed basins will be discovered during the course of routine gravity surveys.

The Mochras borehole, near Llanbedr, Merioneth, drilled in 1967-69 by the Institute of Geological Sciences and the University of Wales to test the theory suggested by gravity surveys that a deep Mesozoic and Tertiary basin exists in Cardigan Bay, recorded a thick lignitic clayey sequence superficially very similar to the Bovey Formation and Lough Neagh Clays. This Tertiary sequence is about 500 m thick and is overlain by 53 m of glacial material. It is possible that ball clays may exist at workable depth, although in general the clays appear to have high iron contents and initial ceramic tests were not encouraging. Ball clays are not likely to be found in recent marine sediments, as known deposits are of non-marine origin.

A number of large Tertiary basins have been discovered on the United Kingdom continental shelf during exploration for hydrocarbons in the North Sea, the Western Approaches of the English Channel and the Irish Sea, and recently the Institute of Geological Sciences discovered a probable Lower Tertiary basin offshore between Lundy Island and Morte Point in north Devon. The basin, which appears to be larger than the Bovey Basin, is also associated with the Sticklepath fault zone. However, it is very unlikely that ball clays could ever be mined below the sea, other than from the shore. Thus deposits beneath Poole Harbour could possibly be worked providing they were below sufficiently thick impermeable cover and the clays beneath Lough Neagh might be worked if they were found to be of high enough quality.

A special report on ball clay resources was published by the Geological Survey in 1929, describing what was known of the geology, mineralogy and properties of the clays, although no quantitative assessment of reserves was made. The Report of the Mineral Development Committee in 1949 gave some tentative estimates of reserves based on indications only. Although detailed reserve figures are not available, reserves would appear to be sufficient for the foreseeable future provided that planning consents are forthcoming. However, any discussion of ball clay reserves must take into account the many different grades of clay which are required to produce the various blends. The lower quality clays occur in large quantities but reserves of the higher quality, white-firing clays are not so extensive. These are largely restricted to the Bovey Basin and because of their comparative rarity throughout the world, are in high demand. Until recently most commercial drilling and other assessment work was carried out on an irregular basis. However, in the last decade or so, with takeovers and mergers in the industry, a more systematic approach has been adopted enabling long term planning and development of resources to be made, and ensuring that a wide diversity of clays come under the control of one company so that the required grades are available for blending.

However, the ball clay industry, particularly in the Bovey Basin and Dorset, is coming into increasing conflict with other forms of land use and in view of the relatively small areas in which the ball clays deposits occur, there is an increasing problem of sterilization of potential reserves. While not urgent a quantitative and qualitative assessment of the extent of ball clay resources in parts of the Bovey Basin and, in particular, Dorset where the area involved is considerably larger and conflict with other forms of land use greatest, would therefore greatly assist both land use planning and the industry and could help avoid sterilization of potential reserves. However, the cost of a detailed evaluation of the clay potential of the Dorset basin by known methods would be prohibitive.

## Land use

Land with planning permission for ball clay extraction, both opencast and underground, totalled about 2,160 hectares in 1972. Of this total, about 340 hectares were in the Petrockstow Basin ( with a further 370 hectares for prospecting only), about 1,218 hectares in the Bovey Basin and about 600 hectares in Dorset (of which only 180 hectares were for opencast working). However, the total area affected by working is small compared with permission areas and opencast sites generally range in size from about 0.5 to 20 hectares. All existing workings are subject to permissions under the Town and Country Planning Acts, which normally include restoration conditions where surface extraction or processing is involved. Subsidence resulting from the old vertical shaft method of ball clay mining (*see* Technology) is often extensive but irregular. The sides of the shaft often collapsed, producing a 'pockmarked' landscape. However, old shafts within the control of the operators have now been filled in and the effect on the landscape is generally minimal. The new method of drift mining may also give rise to subsidence, particularly when clay extraction is at shallow depth. Subsidence is generally relatively uniform, although there has been some recent shallow flooding of agricultural land due to mining. In opencast workings the stability of slopes and benches is a minor problem in some pits where the more plastic clays are worked. The proportion of waste not back-filled into workings is relatively low; moreover underground mining produces very little waste even during development. Poor clays or grades with little commercial appeal may be stockpiled around pits. Where spoil tips do exist they are usually small, flat-topped and naturally regenerate as heath. Although outcrops of clay are often grey or off-white so that before growth occurs, old workings sometimes have a marked visual impact, abandoned pits fill with water and are quickly colonised by plants. The Dorset heaths have thus not been altered visually to any great degree by clay-working, as the undisturbed land tends to alternate between hummocky sands and marsh often underlain by clay.

Nonetheless with the increasing size of opencast operations studies in the after-use and restoration of worked areas to heathland is important and work of this nature is already in hand. The main difficulty in restoring the deeper pits, which have resulted particularly from increased mechanisation, is the lack of available fill; unlike china clay pits, the deposits are worked out completely and so can be filled, but little overburden or waste is produced. In some cases pits are worked so that graders dig the overburden and waste and infill the worked out area as a single earth-moving operation. The extension of underground working will not provide enough waste to fill all the surface pits. In areas adjacent to Poole, Bournemouth and Newton Abbot abandoned pits have been filled with domestic and industrial wastes, and some have then been used for industrial and residential development. Abandoned pits have also been used for amenity purposes in a number of cases, especially where these are water-filled; for example, one landowner has allowed working on condition that the pit is left wet to provide facilities for duck shooting. Rivers and drainage are occasionally affected by subsidence and discharge of fines, but there is no evidence to suggest that the latter are toxic. Angling and fishing interests have acquired leases over a number of abandoned clay pits.

Local conflict of interest may arise where clay workings extend to the edges of urban areas, due to the presence of plant and mine headgear, lorry traffic and the visual effects of workings. The operators endeavour to alleviate such problems by taking clay to central processing plants and by the careful routing of lorries, in some cases, within their own property. Dust is generated, particularly in dry weather and during processing. A certain amount of dust is discharged from dry milling plants but emissions are low and within the required standards. The bulk of the clay from all three areas is transported by road either for processing or to customers. Some congestion in the holiday season exists on the route from north to south Devon. Journey times are, however, planned to avoid the worst periods.

The cost of producing ball clay is increasingly being affected by land-use planning requirements – the planning procedures themselves are becoming increasingly time-consuming and costly – although other costs are still by far the most important.

The Enquiry on the Ball-Clay Industry set up by the Board of Trade in 1946 to suggest ways of ensuring an adequate supply of ball clay for the expanding post-war requirements of the pottery industry, identified two major problems. The first was the need for a policy to increase production in the short term, whilst the second was to ensure that the demand for ball clay could be met far into the future. To help with the long term planning of the ball clay industry, the Ball Clay Standing Conference was constituted in 1949 by the Minister of Town and Country Planning with the following terms of reference:

> 'To co-ordinate the views of the local planning authorities, the Ball Clay industry and the Departments of Government, on the following matters:
>
> a. the provision to be made for the future working of Ball Clay in the Development Plans to be prepared under the Town and Country Planning Act, 1947, for the Counties of Dorset and Devon, having regard to the extent of the Ball Clay resources considered to be workable in future, to the conflicting interests, if any, of agriculture, surface development and amenity, and to any other relevant factors;
>
> b. general problems connected with the granting of planning permission under the said Act for Ball Clay working or waste disposal; including problems connected with the after-treatment of the land or otherwise arising from the imposition of conditions.
>
> c. any related questions of general interest connected with the planning control of Ball Clay working on which the Minister may from time to time invite the views of the Conference.'

The Report of the Conference, published in 1953, recommended a procedure of prior consultation between the planning authority and industry when possible uses of land conflicting with ball clay extraction interests occurred. The procedure was adopted by both Devon and Dorset County Councils and the report remains the standard reference document on ball clay planning problems.

A 'Consultation Area', designed to ensure that ball clay-bearing land was not needlessly sterilised by other forms of development, was defined in each of the three producing areas. The areas involved are about 15,400 hectares in Dorset, about 2,700 hectares in the Bovey Basin and about 1,300 hectares in the Petrockstow Basin. The 'Consultation Line'(*see* Figs 2-4) generally coincides with the outcrop of the clay-bearing formation, except for land allowed for associated development and with the exclusion of land of high agricultural value, land in National Parks, some areas required for the protection of fauna and flora of special interest and land required for the expansion of existing settlements. This consultation system has proved helpful, although it is not always possible to test all land for ball clay prior to development for other purposes, particularly in Dorset, where the areas involved are large.

In Dorset, substantial areas of the Bagshot Beds outcrop were not included in the Consultation Area; in the western part of the basin there is little evidence of the occurrence of ball clay and in the area bounded by Broadstone, Lytchett Minster, Wareham and the northern shore of Poole Harbour the clays found were generally confined to the stoneware variety and were excluded. The working of stoneware clays in this area, largely for pipe manufacture, has now virtually ceased and the area is under great pressure from the urban expansion of Poole and large areas have already been developed. In addition, within the present Dorset Consultation Area, large areas are effectively sterilised by National Nature Reserves, the policies of some large estate owners and because land is used for military training. However the recent Defence Lands Committee report proposed that the land held by the Ministry of Defence in the Lulworth-Tyneham-Povington area should be relinquished. This could be of great significance to the ball clay industry as the important belt of ball clay lying immediately north of the Purbeck Hills extends westwards into Ministry of Defence land on which there is already one large opencast, at Povington, which at present can only be worked at certain times. However, the needs of the ball clay industry would be among the many land use demands likely to be put on the area. More recently, however, it has been announced that the Ministry of Defence proposes to retain the area.

The conflict between nature conservation and ball clay extraction is most acute in Dorset as the Bagshot Beds form a large area of natural heathland, part of which has been afforested, which supports a wide variety of fauna and flora including quite rare species. Most of the area is a scheduled Area of Outstanding Natural Beauty and within or adjacent to the Dorset Ball Clay Consultation Area there are four National Nature Reserves (Morden Bog, Big Wood at Arne, Hartland Moor and Studland) and six Sites of Special Scientific Interest (parts of Poole Harbour Marshes, Arne, Winfrith Heath, Povington-Creech-Grange Heaths, Studland and Godlingston Heaths and Brownsea Island). Agricultural land, including arable and good grazing land is restricted to the area around Wareham and the main river valleys, and the southern edge of the area.

The Bovey Basin comprises mixed agricultural land, park land (Stover Park), extensive afforested areas, scrub, common, semi-urban land and the eastern edge of the Dartmoor National Park, which is excluded from the Consultation Area (Fig 2). There are two Sites of Special Scientific Interest, the Southacre ball clay pit and Chudleigh Knighton Heath.

In the Petrockstow Basin the land consists of low-grade grazing, marsh, wood and scrubland.

The land where the ball clay deposits occur is of low relief, the landscape values being fairly low in the Petrockstow Basin, average to attractive in the Bovey Basin and usually high in Dorset, particularly when viewed from the Purbeck Hills. The latter area is much frequented by visitors to Swanage, the Nature Reserves, Corfe Castle and Poole Harbour, but the workings are usually well hidden and there is no evidence to suggest that visitors are discouraged by the extraction of ball clay. Indeed an abandoned clay pit, the Blue Pool, is a tourist attraction.

Ball clay is a mineral of high export value. High-grade deposits are rare, both in the United Kingdom and in the world in general, and there are probably no more than three or four foreign deposits comparable in grade and size to those in the United Kingdom. Ball clay is an important raw material for the manufacture of a variety of ceramic products, which are in turn major items of export. However, ball clays may vary in quality, both vertically and laterally, over a few metres so that a wide range of working faces are required to maintain the grade. This also means that without close drilling throughout the three main basins, few areas within them can be said to be completely devoid of commercial grades of ball clay. It is therefore very important that potential reserves of ball clay are full investigated to prevent sterilization by other forms of land use and are protected until such investigation can be undertaken.

## Properties and uses

Ball clay has a wide variety of uses but its traditional and most important application is in the manufacture of pottery or whiteware, including domestic tableware, wall tiles, sanitaryware and electrical porcelain. Some siliceous ball clays can be used to produce satisfactory bodies without further additions, but ball clays are normally used in varying proportions to impart certain properties to various ceramic bodies during manufacture. These properties include high plasticity, which facilitates the shaping of the body, and high dry strength, which eases the handling of the dry unfired ware. In addition, ball clays have rheological properties of importance during slip-casting,* fire to a white to ivory colour and contribute to vitrification during firing because of the presence of mica. The high plasticity and bonding properties of ball clays are also utilised in the manufacture of various refractory bodies but ball clay has also a number of non-ceramic applications including as a binder in animal feedstuffs, as an anti-caking agent in fertilisers and as a filler in rubber and plastics.

The properties of the ball clays from the three producing areas vary considerably from bed to bed, due mainly to changes in mineralogical composition and such other factors as particle size distribution. As a result, direct substitution for different uses is limited. The range of mineralogical compositions found in the three producing areas is shown in Table 1.

*The slip, a suspension in water of clay and/or other ceramic materials, is poured into a plaster mould which absorbs a proportion of the water so that the body builds up on the wall of the mould.

**Table 1 Mineralogical compositions of ball clays, including siliceous ball clays**

| | *Per cent* | | |
|---|---|---|---|
| | *Petrockstow Basin* | *Bovey Basin* | *Dorset* |
| Kaolinite | 33-68 | 20-90 | 20-83 |
| Quartz | 15-48 | 0-60 | 5-60 |
| Mica | 0-22 | 0-40 | 0-30 |
| Organic Matter | 0-3 | 0-16 | 0-8 |

(After: D A Holdridge. *Trans.Br. Ceram. Soc.,* 1956, Vol. 55, No.6, p.392.)

Ball clays usually contain disordered kaolinite, although certain higher stratigraphic horizons in the Bovey Basin contain well-ordered kaolinite. The latter ball clays have a higher kaolinite content and a lower proportion of quartz and mica, so that they have properties rather similar to china clay, being white firing and refractory, but they are more plastic and have much higher dry strengths. They are however less plastic than ball clays containing disordered kaolinite.

The high plasticity and dry strength of ball clays appear to be associated mainly with their fine particle size and consequently large surface area, high clay mineral content and the presence of colloidal carbonaceous matter coating the clay mineral particles. Increasing quartz content generally reduces the plasticity and dry strength of a clay, although the coarser grained nature of the quartz gives siliceous ball clays a faster slip-casting rate. Best quality ball clays contain 60 per cent or more of particles less than 0.5 micron e.s.d. (equivalent spherical diameter) and up to 90 per cent less than 1 micron e.s.d. The Dorset ball clays are the most highly plastic, due mainly to their extreme fineness. Increasing carbonaceous content also improves the plasticity and green and dry strength of a clay, hence the 'black' carbonaceous clays of the Bovey Basin are more plastic than the 'blue' clays. However,some of the ball clays of the Petrockstow Basin owe their high green and dry strengths to the presence of small amounts of montmorillonite and mixed layer mica/montmorillonite. One important property of ball clays is their white or off-white fired colour, due to low iron content. The presence of discrete particles of siderite and marcasite can, however, cause specking in the fired body so they are eliminated by careful selection of the clays. Anatase produces buff fired colours rather than specking. The ball clays of the Bovey Basin exhibit the whitest fired colours, the carbonaceous clays usually being the most white firing, the carbon reducing ferric to ferrous iron. Dorset ball clays have a high disordered kaolinite content and their off-white fired colour may be due to substitution of a small amount of iron in the kaolinite lattice.

Some years ago a scheme for classifying their clays from the Bovey Basin was developed by Watts, Blake, Bearne and Company Limited based on work by the British Ceramic Research Association. The classification is as follows:

Group I – Extra-white firing, high kaolinite, carbonaceous, refractory clays, which are easily deflocculated and produce stable casting slips.

Group II – Dark-blue clays, plastic with good workability and high dry strengths, which fire to a white colour between 1,000 °C and 1,100°C, and an off-white colour above this range.

Group III – Light-blue clays, non-carbonaceous and exhibiting a high degree of plasticity, which fire to an off-white or ivory colour at temperatures above 1100°C, owing to a higher content of $Fe_2O_3$ and $TiO_2$.

Group IV – Siliceous clays, which are non-carbonaceous and contain a high proportion of free quartz. They are coarse grained and buff coloured when fired and have fast casting rates.

There is a progressive decrease in kaolinite content from Group I to Group IV with a corresponding increase in quartz content. Although the scheme groups the clays in a useful form it now appears to be of limited value since the clays from the three main deposits vary considerably and the grouping cannot, therefore, be completely applied to the Petrockstow Basin and Dorset. In addition, clays from the Petrockstow and Bovey Basins are now blended together.

The wide variation in the properties of ball clays makes blending essential in producing uniform and consistent grades and in the past it was usual for the potter to buy a number of grades which he blended to conform with his own requirements. However, in modern ball clay practice the producers carry out the blending and market a range of standard grades. As a result of recent mergers, the total number of grades available has been reduced.

The more important ceramic items in which ball clays are used in body compositions are wall tiles, fine earthenware, vitreous-china sanitaryware, electrical porcelain insulators and stoneware. Wall tile manufacturers, the largest consumers of ball clays, require strong, vitreous ball clays of low carbon content, which fire to a cream/buff colour. Earthenware, which consists of a white or cream body, porous when fired and usually covered with a transparent glaze, requires a highly plastic, clean burning clay. Earthenware bodies (amongst others) are used in the production of domestic tableware and artware. Vitreous-china sanitaryware has a white body which vitrifies and is glazed on exposed surfaces: the clay should have good casting properties, be white-burning and produce a slip of low thixotropy. Electrical porcelain insulators are usually vitreous, have a high electrical resistivity and usually bear a brown glaze: the clays required should have high green and dry strengths and should not be prone to cracking on drying. Stoneware is a dense, impermeable, hard, opaque ware, usually with a buff or ivory colour, which is often covered with a coloured or opacified glaze and is used for some tablewares, kitchenware and chemical stoneware. Siliceous ball clays are used in its manufacture because they contain a relatively high proportion of mica which acts as a flux and can therefore be used without additions. Certain Carboniferous fireclays and shales are also used in the manufacture of stoneware. Small amounts of ball clay may also be used in the manufacture of porcelain and bone china to increase the plasticity and strength of the body. Lower grades of ball clays stained with iron oxides may be used in the manufacture of floor tiles, where a cream, buff or red fired colour may be desirable. Ball clay is sometimes used in an engobe, which is a white slip applied to various clay bodies, such a sanitary fireclay ware, and subsequently glazed. Small quantities of ball clay (6 to 7 per cent) are also used in enamelling clays, which are used to promote adhesion of the ground enamel to the metal before firing.

**Table 2 Typical compositions of some ceramic bodies**

| | *Weight per cent of total solids* | | | | |
|---|---|---|---|---|---|
| | *Ball clay* | *China clay* | *Flux*[1] | *Quartz*[2] | *Others* |
| Wall Tiles | 30 | 20 | – | 40 | 10 Limestone |
| Earthenware | 25 | 25 | 15 | 35 | – |
| Vitreous china sanitaryware | 20-30 | 20-30 | 15-25 | 30-40 | 0-3 Talc |
| Porcelain | 10 | 60 | 15 | 15 | – |
| Insulator porcelain | 30 | 20 | 25 | 25 | – |
| Engobe (for sanitary fireclay ware) | 5-15 | 30-50 | 20-35 | 15-30 | – |

1 Usually potash feldspar, nepheline syenite and, formerly, china stone.

2 Silica sand or calcined flint.

There has been a continuous decline in the number of plants producing structural goods from siliceous ball clay and there are now no brickworks using ball clay in Devon or Dorset and the last stoneware pipe manufacturers in both Devon and Dorset have closed in recent years.

Ball clay is used in a number of refractory compositions to facilitate bonding and shaping of less plastic materials, for example fireclays, sillimanite minerals, carbon (graphite, coke or charcoal), grog (a specially fired and crushed clay), silicon carbide and occasionally chromium minerals. Ball clays may be used in ladle brick and casting pit refractory jointing materials, monolithic materials (castables and rammed lining compositions) saggars and other items of kiln furniture. An allied use is in bonding for the production of thermal insulating materials such as diatomite and 'burn-out' compositions which include combustible material, which burns out to produce a porous structure. The main requirements are a high alumina content (37 to 43 per cent when fired) and generally low alkali values (especially in saggars); low iron and titanium may be important when used in high-grade refractories, for example sillimanite, although fired colour is usually unimportant. As with other high alumina clays, ball clay may be calcined to produce a refractory chamotte or grog, which is used in refractory and ceramic body compositions to reduce shrinkage on firing.

In addition, ball clay may also be used as a binder in the production of grinding wheels and other abrasive implements incorporating silicon carbide, corundum, emery and other hard materials. In the foundry industry, ball clay and ball clay/bentonite mixes were sometimes used for bonding moulding sands, although this is rarely the case to-day.

Ball clay is also used as a low priced, inert filler in plastics and rubber for which the clay should be free of grit, carbonaceous material and iron compounds; amine coated and calcined ball clays may also be used for this purpose. Small amounts of very fine pure clay are used in pharmaceutical preparations. An important and increasing market for ball clay is as an anti-caking agent in fertilisers and for pelletising animal feedstuffs.

**Price and cost**

Ball clay is sold ex-works as either shredded or ground clay the higher price of the latter incorporating processing, bagging and palleting costs. Each pallet holds forty or fifty 25 kg bags and is usually non-returnable. In 1972, average ball clay prices were as follows:-

Ex-works 'top quality' clays:

Shredded £6 to £8 per tonne
Ground and bagged £13 to £19 per tonne

Ex-works 'lower quality' clays:

Shredded £2 to £5 per tonne
Ground and bagged £8 to £12 per tonne

*Transport*

Ball clay in north and south Devon can take advantage of British Rail's clayliner trains, developed for carrying china clay to the Potteries and the substantial growth in business has proved that the rail service is highly competitive.

Large amounts of clay are transported by road from the Petrockstow Basin to south Devon on the route A382-A30-A386, which is very narrow in parts and much used in the holiday season. Alternative routes are considerably longer. Parts of the route are due for general improvement to dual carriageway standards and a minor by-pass is also planned. Some of the clay is carried by rail but this is usually taken to destinations outside the county as rail transport is not generally economic to works in the Bovey Basin. The branch line from Newton Abbot to Bovey Tracey runs through the south Devon clay area and serves the two works. Most of the clay from the Dorset area is transported by road, although ECC Ball Clays Limited have a private siding at their Furzebrook Works and some 25 per cent of their output is transported by rail.

Teignmouth is the main port used for shipping Devon ball clays, mainly to markets in Europe. Exports of ball clay amounted to 307,000 tonnes in 1972 representing some 90 per cent of the total traffic through the port. Ball clay is also occasionally exported through Par, Fowey and Plymouth, but at substantially greater cost. In addition, clay is taken to deep sea ports on Merseyside and in South Wales for shipment to numerous small overseas outlets outside Europe. The British Rail port of Fremington which used to handle clay from the Petrockstow Basin has been closed and Bideford now regularly handles clay. Prior to the First World War clay was shipped along the Stover Canal in south Devon and from a number of wharves on the south side of Poole Harbour. Poole is used for shipping Dorset clays on a small scale.

Teignmouth can currently accommodate vessels of up to 1,000 tonnes deadweight, while Poole can accept vessels of at least 3,350 tonnes deadweight. The tonnage of ball clay shipped through Teignmouth rose from 73,500 tonnes in 1949 to 358,000 tonnes in 1969, although it subsequently declined to about 307,000 tonnes in 1972. Poole handles about 10,000 to 20,000 tonnes a year. Tonnages of clay shipped through Par, Fowey and Plymouth are not subdivided by type, but include much greater amounts of china clay than ball clay.

Sedimentological and flow investigations have been made of Teignmouth Harbour with a view to improving access for larger shipping. This is of utmost importance to the ball clay export trade to enable the industry to make use of larger vessels and, therefore, reduce costs. In 1965, the ratio of vessels above and below the 800 tonnes carrying capacity was over 1 to 4. In 1972 the ratio was 1 to 1. Modernisation at Poole Harbour will also enable it to cope with any increased ball clay shipments.

## Technology

### *Extraction*

Ball clay is won by both opencast quarrying and underground mining, some two-thirds of the total output being produced in open pits. The original method of extracting ball clay by hand cutting with a tubal was not entirely replaced until the 1940's when pneumatic hand spades were introduced.

However, these have now been largely replaced, except for some underground work, by fully mechanized equipment.

In the opencast operations, overburden consisting essentially of alluvial sand and gravel, silt and sand, is removed by dragline excavators, scrapers and bulldozers and stockpiled for future reclamation work. Overburden thicknesses vary but average 6 m to 9 m in the Bovey Basin, where the largest pits are about 40 m deep. However, in some deposits there may be as much as a further 50 per cent waste because the ball clays are interbedded with lignites, lignitic clays and silts. In Dorset, the maximum overburden removed is about 20 m. Clay extraction is now largely undertaken by backhoe hydraulic excavators and dragline excavators, although in the Bovey Basin small bucket-wheel excavators have been introduced and operators and machines can now extract specific horizons or grades of clays to very fine limits. This is particularly important where the high-carbon, white-firing clays are interbedded with lignite.

The clay is extracted in benches 3 m to 6 m high and normally a temporary road of sleepers is laid to each working face for access, large automatic pumps being used to keep the pits dry. The more siliceous ball clays are generally free of lignitic waste material and therefore do not require the same degree of selective mining.

Better drainage techniques and mechanisation has allowed the size and depth of open pits to be increased and old mine workings are frequently broached. Where slope stability is a problem deeper open workings may not be possible if the necessary land to maintain the pit sides is not available. This may be a future problem in the Bovey Basin where the workings are close together. However, the proportion of clay, particularly of lower grades, produced from open pits is likely to increase in order to withstand competition both from European producers, who are abandoning underground mining as uneconomic, and substitute materials (for lower grade clays).

Before 1960 most underground mining in Devon was carried out from headings driven along the strike of the clay bed for up to 60 m on either side of the bottom of small shafts sunk to a maximum depth of 45 m. The workings fanned out from these main headings and the area was worked back to the shaft bottom, the worked-out area having an irregular ellipsoidal shape. The workings were then abandoned, the shaft filled in and a new shaft sunk. One of the main difficulties of this method of mining is ground movement caused by the plastic nature of the clay, which can effect the alignment of the shaft and cause floor heave where long roadways are involved. Because of these difficulties, this old method of shaft mining has been replaced by drift mining which enables clays to be extracted from much greater depths. The drifts also have a longer life, up to 25 years, and an annual output of some 10,000–30,000 tonnes. Steel lined and timbered drifts are driven steeply at first, until the clay is intersected, and then for as far as about 800 m down the dip of the bed. From this main haulage way, levels are driven at right angles with return ways parallel to the main haulage to improve ventilation. Clay is extracted from retreating faces, support pillars being left under roads and buildings, but elsewhere only enough support is retained to permit subsidence to be controlled.

The clay is mined by hand with pneumatic spades, although more recently drum cutters for mechanised mining have been introduced in the Bovey Basin. A minimum working thickness of about 2 m is generally mined and sufficient clay must also be left in the roof to provide some support and an impervious seal to water. The clays are highly plastic near the surface or when exposed in open pits, but contain less water and become more competent below about 50 m of cover, as do the accompanying sands and lignites. The largest underground mining operations are in the Bovey Basin, where they are favoured by the general decrease in dip towards the centre of the basin. The workings extend to a depth of about 135 m, but it is generally believed that present mining methods would permit working down to 200 m. However, because of the higher costs involved, only a limited range of high grade clays will continue to be mined. There are now no working mines in the Petrockstow Basin, but in Dorset some 40 to 60 per cent of the total production is mined. The presence in Dorset of clay lenses, which may not outcrop at the surface, necessitates the sinking of vertical shafts to work these deposits, because of the difficulties of driving drifts through unconsolidated water-bearing sands. These shafts are rarely more than 35 m to 50 m deep.

The clay is selectively mined at the face, where the skill of the miner is very important in distinguishing the various qualities. Rail cars are used for transporting the clay to the mine head, where it is stored, according to grade, in overhead hoppers. Dumpers, including a recently introduced articulated version, are used for transporting the clay from pit or mine to the processing plant. However, conventional lorries are used extensively for the longer hauls involved in Dorset.

*Processing*

The properties of ball clays vary considerably from bed to bed and also vertically and laterally within the same bed. The production of uniform and consistent grades is, therefore, heavily dependent on careful selection at the working face and frequent testing and blending to produce the required qualities. Ball clay processing consists essentially of shredding, drying, grinding and blending, the fine-grained nature of the clay and its impurities making beneficiation, as yet, impracticable.

After transport from the pit or mine, the clay is stored in covered bays, where it is partially air-dried, prior to being fed into mobile or permanently fixed shredders which consist of cylindrical hoppers mounted above a circular, revolving plate in which sharp knives are formed. The lump clay is cut into small pieces, ranging in size from 9 cm to dust, which fall onto a high-speed conveyor and are thrown into covered storage sheds. Shredding facilitates the loading, discharging and mechanical handling of the clay, and also gives it a more uniform quality through mixing. About 75 per cent of the total ball clay sold is in shredded form. However, increasing quantities of ball clay are dried and milled to fine powders, air-classified and packed in bags. This has the further advantage that the moisture content of the clay is reduced from about 15 per cent for shredded clay to about 1 per cent, which in turn gives savings on transport costs. Watts, Blake, Bearne and Company Limited produce a calcined ball clay as a refractory chamotte or grog which is sold as pellets or powder, and both companies produce amine-coated clays, with modified surface properties, for certain filler applications. Blending two or more different clays is normally carried out at the shredding stage and is an essential part of ball clay processing, an elaborate system of quality control being carried out to ensure uniformity and consistency of supplies.

As the demand for high quality clays outstrips resources, or the cost of extracting small pockets of high-grade material rises appreciably, upgrading of the large reserves of lower grade material might become feasible as is the case in other mineral industries. Sands with a high clay content are already being stockpiled in the event of the separation of the clay becoming economically feasible. However, the removal of quartz, iron oxides and sulphides intimately associated with ball clay, is likely to prove an extremely difficult mineral separation problem because of the fine-grained nature of the material. Although there is a strong trend toward more exacting specifications and consistency of grade, there have been some adjustments so that the appropriate, rather than unnecessarily high grades of ball clay are used. In addition, some intermediate grades are produced by blending higher and lower qualities. Clays with a poor fired colour may be used in the manufacture of floor tiles, certain refractories and in some non-ceramic applications where colour is unimportant.

The lignites and sands interbedded with ball clays are largely discarded as waste. However, the lignite beds of the Bovey Basin are the only extensive deposits in Great Britain, although lignite is also found associated with the Lough Neagh Clays in Northern Ireland and has been worked for fuel on a small scale in the past. The Bovey lignites were originally worked as a domestic fuel in the 17th century before extraction of ball clay began, and were later used for lime burning and to fire pottery and bricks, but unfortunately they produce black smoke and have a sulphurous smell. During the Second World War, lignite was used to prepare montan wax (a bituminous wax extracted from lignite), but this proved to be uneconomic. Plans to work the lignites on an extensive scale did not come to fruition. Small amounts of lignite are at present sent to a company producing a soil conditioner.

Cassiterite (tin oxide) derived from the veins of the Dartmoor Granite occurs in small quantities in the alluvial sands and gravels of the River Teign in the Bovey Basin. These gravels are removed as overburden by Watts, Blake, Bearne and Company Limited and treated to produce a saleable concentrate of cassiterite and sand and gravel for aggregate. Similarly, the Tertiary sands and silts of the Bovey Basin may prove worthy of investigation for their cassiterite content. In Dorset, the small independent ball clay producer, The Wareham Ball Clay Company, produces sand and gravel in association with ball clay from an operation on Stokeford Heath.

## Production

Ball clay deposits are not widely distributed throughout the world and clays with comparable properties to British ball clays are worked only in Czechoslovakia and in western Kentucky, Tennessee and Mississippi in the United States, although slightly inferior clays are also produced in Federal Germany, France and Spain. Because of the comparative rarity of this essential ceramic raw material, the United Kingdom is both the leading world producer and exporter of ball clay.

Ball clay is thought to have been produced in Dorset since Roman times, but records indicate that production in the Petrockstow Basin did not begin until about 1680 and in the Bovey Basin until about 1693. Production data prior to 1920 is, however, scattered and incomplete. Official statistics have been recorded since 1920 under the heading 'Potters' clay (including ball clay).' The term 'potters' clay,is applied rather loosely to include a variety of other clays used in the manufacture of coarse earthenware, sanitaryware and stoneware, for which colour is usually only of secondary importance. However, by far the major proportion of United Kingdom potters' clay production consists of ball clay. Total production of potters' clay (including ball clay) in the period 1920 to 1973 (*see* Fig 5) has amounted to approximately 20 million tonnes and figures for the period 1950 to 1973 are shown in Table 3.

**Table 3 Great Britain (a): Production of Potters' clay (including ball clay), 1950-1973**

| | *Thousand tonnes* | | *Thousand tonnes* |
|---|---|---|---|
| 1950 | 385 | 1962 | 579 |
| 1951 | 401 | 1963 | 602 |
| 1952 | 393 | 1964 | 626 |
| 1953 | 349 | 1965 | 647 |
| 1954 | 366 | 1966 | 692 |
| 1955 | 419 | 1967 | 692 |
| 1956 | 435 | 1968 | 742 |
| 1957 | 468 | 1969 | 830 |
| 1958 | 456 | 1970 | 837 |
| 1959 | 453 | 1971 | 732 |
| 1960 | 530 | 1972 | 699 |
| 1961 | 543 | 1973 | 755 |

*Source:* Department of Industry.

(a) The Northern Ireland Annual Statement of Mineral Production does not differentiate potters' clay or ball clay from other clays.

In 1973, however, production of ball clay, including some stoneware clay in Staffordshire, was separately recorded for the first time, and amounted to 741,900 tonnes.

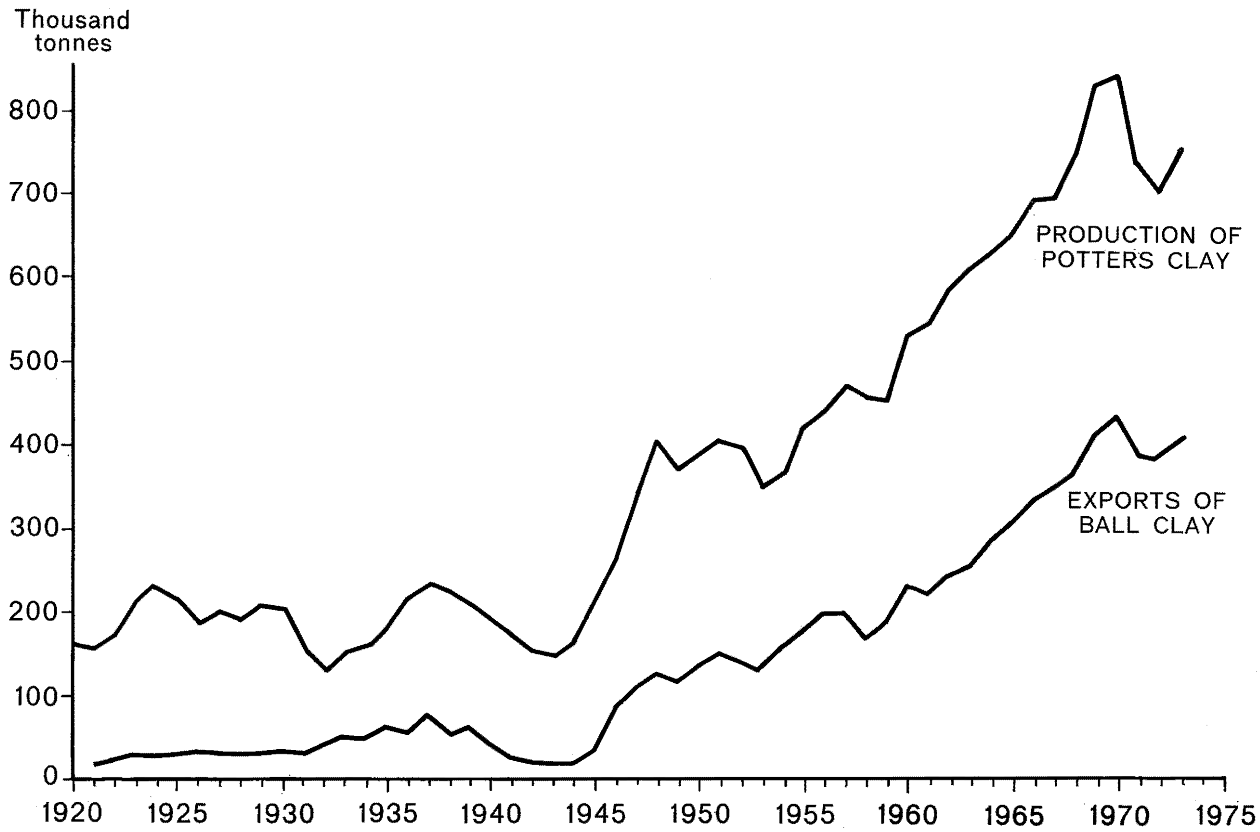


Fig 5 Great Britain: Production of potters' clay (including ball clay) and exports of ball clay, 1920-1973

An independent indication of United Kingdom ball clay production (excluding all other clays) is shown in Table 4, which gives sales of ball clay in the period 1962-1973 by members of the British Ball Clay Producers' Federation. Output by non-members of the Federation has been small: in recent years only one independent producer has contributed some 10,000-15,000 tonnes a year. The differences between the figures in Tables 3 and 4 are largely accounted for by potters' clay other than ball clay (but note also that Table 4 refers to sales).

**Table 4 United Kingdom: Sales of ball clay, 1962-1973**

| | Tonnes | | Tonnes |
|---|---|---|---|
| 1962 | 455,367 | 1968 | 631,271 |
| 1963 | 480,804 | 1969 | 690,781 |
| 1964 | 537,546 | 1970 | 732,130 |
| 1965 | 557,376 | 1971 | 661,978 |
| 1966 | 608,242 | 1972 | 672,034 |
| 1967 | 622,216 | 1973 | 721,512 |

*Source:* British Ball Clay Producers' Federation.

It is estimated that the Bovey Basin accounts for about 67 per cent of the total United Kingdom production of ball clay with approximately 21 per cent produced in Dorset and 12 per cent in the Petrockstow Basin.

**Overseas trade and consumption**

The United Kingdom has been a leading world exporter of ball clay since the latter half of the 19th century and is the most important source of high quality ball clay in the world. Exports in 1973 amounted to 404,720 tonnes, representing about 56 per cent of total sales, and consisted mostly of high quality, white-firing, high-strength clays with good casting properties from the Bovey Basin. Over 70 per cent of the clay produced in the Bovey Basin is exported and the corresponding figures for the Petrockstow Basin and Dorset are 50 per cent and 15 to 20 per cent respectively. Ball clay is recorded by HM Customs and Excise under the heading 'Ball clay, whether or not calcined', code No 2507 0330: exports for the period 1950-1973 are shown in Table 5.

**Table 5 United Kingdom: Exports of ball clay, 1950-1973**

| | *Thousand tonnes* | | *Thousand tonnes* |
|---|---|---|---|
| 1950 | 140 | 1962 | 247 |
| 1951 | 151 | 1963 | 254 |
| 1952 | 140 | 1964 | 288 |
| 1953 | 128 | 1965 | 307 |
| 1954 | 160 | 1966 | 334 |
| 1955 | 176 | 1967 | 344 |
| 1956 | 198 | 1968 | 363 |
| 1957 | 200 | 1969 | 415 |
| 1958 | 165 | 1970 | 434 |
| 1959 | 189 | 1971 | 381 |
| 1960 | 233 | 1972 | 380 |
| 1961 | 221 | 1973 | 405 |

*Source:* HM Customs and Excise.

Ball clay is exported to more than forty different countries throughout the world, although about 90 per cent is taken by Western Europe, Italy being by far the most important single market (Table 6).

**Table 6 United Kingdom: Exports of ball clay, 1971-1973 by countries**

| Country of destination | 1971 Tonnes | 1971 f.o.b. Value | 1972 Tonnes | 1972 f.o.b. Value | 1973 Tonnes | 1973 f.o.b. Value |
|---|---|---|---|---|---|---|
| Italy | 94,277 | £602,514 | 101,248 | £669,183 | 116,832 | £831,382 |
| Netherlands | 35,267 | £179,482 | 39,280 | £197,009 | 39,549 | £192,320 |
| Sweden | 30,218 | £185,141 | 25,723 | £164,321 | 26,879 | £185,904 |
| Federal Germany | 34,519 | £217,637 | 36,418 | £226,617 | 34,482 | £217,700 |
| Spain | 23,673 | £147,701 | 28,229 | £179,988 | 34,930 | £236,149 |
| Greece | 29,100 | £128,378 | 32,930 | £162,746 | 34,350 | £188,377 |
| France | 21,571 | £135,733 | 23,584 | £158,820 | 26,287 | £208,424 |
| Australia | 8,156 | £120,203 | 611 | £ 10,541 | 700 | £ 13,820 |
| Belgium | 20,841 | £120,926 | 19,938 | £121,143 | 23,913 | £151,121 |
| U.S.A. | 13,490 | £117,101 | 8,852 | £ 81,613 | 10,861 | £103,377 |
| Finland | 22,198 | £104,827 | 16,905 | £ 94,487 | 11,132 | £ 67,919 |
| Denmark | 10,487 | £ 46,683 | 8,840 | £ 44,609 | 7,355 | £ 41,623 |
| Other countries | 37,533 | £312,871 | 37,875 | £384,586 | 37,450 | £398,704 |
| Total | 381,330 | £2,419,197 | 380,433 | £2,495,663 | 404,720 | £2,836,820 |

*Source:* HM Customs and Excise.

United Kingdom imports of ball clays are negligible, amounting to only 125 tonnes valued at £6,503 in 1973. Overseas trade in ball-clay, has, therefore, a favourable effect on the balance of payments, approaching £3 million in the same year. The export of finished ceramic products made in part from ball clay has a further favourable effect, although there is no reliable basis for estimating this value; the export value of all finished pottery products in 1973 was £58.3 million .

In 1973 about 317,000 tonnes of ball clay were consumed in the United Kingdom. Approximately one half was used in the manufacture of wall tiles, floor tiles, earthenware, sanitaryware, and electrical porcelain. Roughly one quarter was consumed in various other refractory products and the remaining quarter had non-ceramic uses, for example as a filler in rubber and plastics, as an anti-caking agent in fertilisers and for pelletising animal feedstuffs, the agricultural uses consuming some 30,000-40,000 tonnes a year. Demand for ball clay has always been closely governed by the needs of the ceramics industry, although in recent years the non-ceramic market has had a higher growth rate. The principal reason for the growth in the industry since the war has been a steady growth in exports of about 5.7 per cent a year. Production of potters' clay, including ball clay, has shown a growth rate of 4 per cent a year. British ball clays have acquired a high reputation for consistent quality and are generally recognised as the best available. American ball clays are unable to compete in overseas markets because of the high cost of internal freight, whereas the British deposits, being situated close to ports, are in a good position to serve overseas markets. In Europe, Czechoslovakia, Federal Germany and France are potentially significant competitors, although in general the German and French clays are not so white-firing.

The United Kingdom ceramics industry has also enjoyed a period of high overseas demand for finished ceramic products so that home demand for ball clay has also been strong. Although both home and overseas demand for ball clay decreased slightly in 1971 and 1972 the future trend seems certain to continue to be upward (Fig 5).

**Industry**

There are two major ball clay producers in the United Kingdom, Watts, Blake, Bearne and Company Limited (WBB) and ECC Ball Clays Limited (ECC), a member of the English China Clays Group. WBB (the second largest United Kingdom china clay producer) is probably the largest ball clay producer in the world, with a current annual output of 400,000 – 450,000 tonnes, and ECC accounts for about 230,000–270,000 tonnes a year. Both are public companies which have increased significantly in size in the last few years, particularly through mergers and takeovers. WBB have operations in both the Petrockstow and Bovey Basins, where they have a larger share and more consolidated holdings, and have only recently begun working in Dorset with the acquisition of a clay pit near Lytchett Minster: WBB have also recently acquired an interest in German ball clay production. ECC have operations in all three areas and are by far the largest producer in Dorset. The Wareham Ball Clay Company produces about 10,000–15,000 tonnes a year of powdered and bagged clay from operations associated with sand and gravel workings on Stokeford Heath in Dorset. There are now no stoneware pipe manufacturers in the Bovey Basin or in the Bournemouth-Poole area of Dorset. The only operator working the Lough Neagh Clays in Northern Ireland, the Coalisland Brick and Pipe Company Limited, is a subsidiary of the Hepworth Ceramic Holdings Group. These clays are used in the manufacture of sanitary pipes, but are not suitable for the production of pottery.

There has been a dramatic change since the backward state of the industry was strongly criticised by the Enquiry on the Ball-Clay Industry (1946), which was set up to recommend steps for increasing domestic ball clay production to meet the expanding post-war requirements of the pottery industry. In 1953 eleven companies were producing ball clay regularly and an additional three or four more intermittently; most of these now form part of either WBB or ECC. Rationalisation within the industry has been accompanied by increased mechanisation, both underground and opencast, the introduction of new products and advanced laboratory facilities for quality control, and a spectacular growth in production and exports.

The British Ball Clay Producers' Federation represents the two main producers of ball clay.

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