Sustainable development issues for mineral extraction

the Wareham Basin of East Dorset
Sustainable development issues for mineral extraction – the Wareham Basin of East Dorset

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Cover photograph  
View from Creech Barrow Hill westward along the Chalk ridge  
towards Povington ball clay pit

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*Plate 7*
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The Wareham Basin of East Dorset contains internationally important, but scarce, deposits of ball clay — a clay used in the manufacture of high quality ceramics — and regionally important sand and gravel resources. Elsewhere in the UK, ball clay is confined to only two small areas in Devon. Extensive parts of the Wareham Basin are subject to landscape, and international and national nature conservation designations. These include the Dorset Area of Outstanding Natural Beauty, and candidate Special Areas of Conservation and Special Protection Areas identified or designated in accordance with European Directives. The potential constraints on mineral extraction in the area are, therefore, very extensive and it is becoming increasingly difficult to identify acceptable sites for future mineral working.

On behalf of the Department for Transport, Local Government and the Regions, the British Geological Survey undertook a detailed study of the inter-relationships of the mineral, land use and environmental resources of the Wareham Basin and made recommendations for the future management of these.

The approach taken in, and results of, this research provide an example of how the issues might be addressed where environmental and conservation issues have a major impact on the extraction of minerals elsewhere.

The report recommends that:
- Government should take a view on the national importance of ball clay;
- results of the study should be used for the identification of the extent of commercial ball clay deposits in the area, and the location of these in relation to landscape and nature conservation designations;
- the Geographical Information System and associated database developed for this study should be maintained to provide a framework for future planning, and specifically mineral planning, in the area;
- the options for the supply of ball clay, including alternative sources and materials, should be monitored and reviewed;
- that research on the restoration of mineral workings, especially the re-creation of natural habitats in isolation and as part of an integrated resource and rehabilitation programme, should be promoted by the planning process; and
- that consideration of whether the current approach to safeguarding ball clay resources is adequate.

If these issues cannot be resolved, then it is likely that over the next ten years or so ball clay working in this area will gradually decrease with some effect on local employment and the local economy and, perhaps, on export trade in ball clay.

The databases and maps, which underpin these conclusions, are also set out in a technical report (Bristow et al., 2002), which is available from the British Geological Survey, Keyworth, NG12 5GG. It is recommended that planning for the supply of ball clay and major decisions affecting ball clay production are made following reference to this report.
Minerals are important national resources. Their extraction and use makes an important contribution to our economic well-being and to our quality of life. An adequate supply of minerals is essential for manufacturing, construction and related industries. Recycled materials can meet part of these requirements, but new minerals are also needed.

However, minerals extraction has effects on the landscape, environment, and the quality of life of people living, working and taking their leisure nearby. These impacts need to be minimised through the application of the principles of sustainable development to national, regional and local policies for, and decisions on, the supply of minerals. The overall aim is to meet society’s need for minerals, as far as practicable, at least social, economic and environmental costs. Some major principles in achieving a sustainable supply of minerals are that (MPG 1):

- minerals should be conserved, as far as possible, whilst securing an adequate supply to meet the needs of the economy and society;
- environmental impacts caused by minerals operations and the transport of minerals should be kept to an acceptable minimum through good operational and management practices;
- the production of waste should be minimised and minerals should be used efficiently, taking appropriate account of the use of high quality materials and opportunities to recycle wastes;
- restoration of sites should preserve or enhance the overall quality of the environment after working has ceased and, where appropriate, make contributions to improved habitats and biodiversity;
- areas of designated landscape, nature conservation or heritage value should be protected, as far as possible, from mineral development, and;
- the unnecessary sterilising of mineral resources by using the land permanently for other purposes should be avoided.

Effective planning for the supply of minerals depends, therefore, on identifying the most appropriate locations for extraction, undertaking operations with minimum environmental impacts, and ensuring high quality restoration to appropriate subsequent uses.

It is the function of the town and country planning system to address these objectives through the development plan process, and through decisions and controls on planning applications to extract minerals. Minerals Local Plans should assess the need for future mineral supplies and identify, through general policies and specific allocations, areas in which mineral extraction proposals: (1) might be acceptable and (2) where they will normally be resisted. Since proposals that are in conformity with the plan, and that are acceptable in other respects, will normally be permitted, this helps to give a degree certainty to both the industry and to local residents in respect of proposals for extraction. However, the identification of generally suitable areas depends on a good understanding of both the mineral resources and on constraints to minerals extraction. This requires comprehensive information on the nature and distribution of mineral resources, the characteristics of areas where minerals occur, the likely implications of working these resources both for the environment and for the quality of life of nearby residents, and the likely levels of demand for the mineral. Such information is also needed for the preparation of policies in regional planning guidance and in considering specific planning applications for minerals extraction, or for other forms of development in mineral resource areas.

Most mineral extraction operations have at least some potentially harmful environmental impacts to overcome. These impacts can normally be resolved in the details of a planning application through suitable plan-
ning conditions and sound site management practices. However, some constraints to mineral working, such as international and national nature conservation, landscape and heritage designations, are sufficiently severe that mineral extraction might not be appropriate in most, or even any, circumstances.

If a specific mineral is relatively widespread then there is usually a fairly broad range of options for extraction. If a mineral is nationally scarce or geographically localised then the options for extraction may be very limited. If those same areas are subject to extensive landscape or nature conservation designations, it may be difficult, or impossible, to identify acceptable sites for mineral extraction. The Department for Transport, Local Government and the Regions (DTLR) wished to examine mineral resource and policy issues in such an area in order to identify the best means of approaching the problem. The Wareham Basin in east Dorset was selected as a suitable example.
The Wareham Basin is a geological structure that extends beneath most of eastern Dorset and covers an area of about 330 km² (Figure 1). It contains deposits of interbedded sands and clays, the most extensive and economically important being known to geologists as the Poole Formation. Thin, superficial deposits of gravel and alluvium extensively overlie this formation. The landscape is characterised by broad low hills and valleys with distinctive areas of sombre open heath or enclosed forest confined between the intensive farmland of the higher Chalk ground to the south, west and north, and by Poole Harbour and the sea to the east (Plate 1). Two main rivers, the Frome and Piddle, flow eastwards into Poole Harbour. Only in the east, around Poole and Wareham, is there significant urbanisation.

The Basin contains farmland, coniferous forest and a variety of linked, semi-natural habitats of nature conservation interest, including lowland heath, wetlands, deciduous woodland, grassland, estuaries, rivers and standing water. The presence of these habitats is partly a product of past and current land management practices. They would decline in nature conservation value if not actively and effectively managed with due attention to all parts of the ecosystem. For example, management of heath and marsh is important to prevent gradual invasion by shrubs and trees leading to the climax vegetation community consisting primarily of oak with birch or hazel.

The lowland heath consists of open uncultivated tracts of treeless land dominated by low herbs and dwarf shrubs. This habitat, in particular, has been greatly reduced and fragmented, from about 40 000 ha in the mid 18th century to about 7 000 ha today. Even though the resulting land may be difficult to cultivate and of low agricultural productivity, much of this loss was to arable farming and grassland. Other areas went for forestry and, locally to urban development. However, the recent rate of loss has been very small.

As part of national biodiversity objectives, the re-creation of some of this lost heathland, and other habitats, in the Wareham Basin is proposed. The national biodiversity target for new heathland is 6 000 ha (Anon, 1995), most of which might be met through clearing coniferous forest or reclaiming agricultural land, and part of which is being met through reclamation of mineral workings in the Wareham Basin.

Because of its attractive landscape and rich variety of habitats, the Wareham Basin has very extensive landscape and nature conservation designations (Figure 2). Amongst these is the Dorset Area of Outstanding Natural Beauty (AONB), which includes most of the area south of the River Frome (about 33 per cent of the Basin). International nature conservation sites, include Ramsar sites designated in accordance with the Ramsar Convention, and sites designated as Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Priority Special Areas of Conservation in accordance with European Directives (totalling about 19 per cent). National nature conservation sites, include Sites of Special Scientific Interest (SSSIs) and National Nature Reserves (about 22 per cent).
Figure 1  The extent of the Wareham Basin.

Figure 2  The extent of the major environmental designations in the Wareham Basin.
Most of these areas coincide but, even so, a substantial part of the Basin is subject to some type of international or national designation.

Other national or local designations, including Scheduled Monuments and Conservation Areas, are scattered across the Basin. Groundwater and high-grade agricultural land resources also occur. In addition, there are extensive areas that are in the ownership of the National Trust or under commercial coniferous forest. The Ministry of Defence uses large areas for military training and there are major oil and gas pipelines crossing part of the Basin. In addition, the area is important for tourism and adjoins the Poole-Bournemouth conurbation, one of the fastest growing areas in the country (Figure 3).

The mineral resources of the Wareham Basin include internationally important deposits of ball clay, as well as sand and gravel, and brick clay. The area also contains Europe’s largest onshore oilfield, Wytch Farm, but hydrocarbons fall outside the terms of this study.

There has been a local ball clay industry in the Wareham Basin since the 17th century. Unworked resources are fairly widespread, but a major part of these are within areas that have been identified as worthy of environmental conservation. A key issue is, therefore, the extent to which acceptable new sites for future ball clay extraction can be identified in the Wareham Basin. Ball clay has been worked from both surface pits and underground mines (Figure 4). However, all mines have now closed. Prior to the 1950s most ball clay workings were left to naturally regenerate and over time have changed to heathland or other habitats. However, modern workings now require carefully planned restoration and management to speed up this regeneration process and thereby maximise biodiversity gains.

Sand and gravel are extracted mainly for construction aggregate. They are worked mainly from thin terrace gravel deposits associated with the major rivers, and thicker sand deposits, which commonly occur beneath these. Substantial areas of the main outcrops of terrace gravel have been worked out. Significant outcrops remain, but mainly in scattered and thin deposits. The underlying sands occur in larger quantities. A significant part of the sand and gravel outcrop occurs in areas of international and national nature conservation importance. As with ball clay, very old workings have regenerated to heathland and other valued habitats and again the objective for the future is to accelerate this process to maximise gains.

In most of the area, the responsibility for minerals and waste planning rests with Dorset County Council. The district councils of Purbeck, West Dorset and East Dorset have responsibility for all other aspects of land-use planning. The exception is a small part of the east of the area where Poole Borough Council is responsible for all planning matters (Figure 1).
Figure 3  The extent of selected land holdings and designations in the Wareham Basin.

Figure 4  Extent of ball clay-bearing host clays in the Wareham Basin.
A hierarchy of national and international designations is used to protect areas of important landscape and habitat, and other assets, from the adverse effects of development (PPG7 and PPG9). Restrictive policies apply to minerals extraction in these areas. Thus, for example:

- major mineral developments should not be granted planning permission in an AONB other than in exceptional circumstances and only after a most rigorous examination including:
  - an assessment of need and alternatives;
  - that the development is in the public interest; and
  - the extent to which detrimental impacts can be moderated;

- in respect of SPA and SAC sites designated under the EU ‘Birds’ and ‘Habitats’ directives, respectively, permission may be granted only if:
  - the proposal will not affect the integrity of the site; or if it does that;
  - appropriate conditions can be imposed that will mitigate any adverse effects upon the integrity of the site; or if such conditions cannot mitigate adverse impacts on the site: because
  - there is no practical alternative to the proposal; and
  - that the development must be carried out for imperative reasons of overriding public interest;

- if an application contains all or part of a site designated as of priority SAC status, or supports a priority species, and there is no alternative option, permission will only be granted if the proposed development is:
  - demonstrated to be required for reasons of human health, public safety; or
  - produces beneficial consequences of primary importance to the environment; or
  - any other reason of overriding public interest.

Where either a priority or non-priority SAC and SPA is affected by a permission for development compensatory measures may be required in order to preserve the integrity of Natura 2000, a European-wide network of areas of special conservation interest. There are also provisions for a review of any existing developments that might significantly harm the integrity of a designated European site.

All of these designations occur extensively in the Wareham Basin, particularly in the area south of the River Frome (Figure 2). Therefore, most new proposals for extraction are likely to be subject to very stringent tests and, in some cases, may not be permitted. Key issues are: (1) need for the mineral; (2) the lack of alternatives; (3) the extent to which extraction might affect designated sites, both during and after extraction and; (4) the extent to which site restoration can contribute to achieving environmental improvements, in particular, the re-creation of habitats and tangible benefits to biodiversity.
Despite losses to development, a varied and extensive area of inter-linked, semi-natural habitats extend throughout parts of the Wareham Basin. These grade from shallow waters and mudflats, to mires and reed-beds, wet heath, dry heath and woodland Plates (2-4). These are important nature conservation habitats. The importance of the Wareham Basin to nature conservation is also heightened by its global location where there is an inter-play between southern and northern, and maritime and continental ecosystems leading to an enhanced overall species richness and habitat value. In addition, westerly Atlantic winds, and the absence of industrial complexes upwind, bring unpolluted air favourable to heathers and epiphytes and keep groundwater quality high.

The varied topography, geography, geology and, therefore, soils and groundwater regimes, support a range of heathland habitats, which grade into one another, each with their distinctive fauna and flora, including:

- dry heath – with a water table well below the surface and free draining throughout the year;
- humid heath – with impeded drainage and a water table within 40 cm of surface;
- wet heath – with impeded drainage and the water table within 10 cm or less of the surface; and
- valley mires – with water level at, or above, the ground surface leading to peat formation.

Several habitats that occur within the Wareham Basin have been identified as biodiversity-priority areas that require action to increase their extent. These include dry, humid and wet heathlands, valley mires and acidic grasslands. Given sufficient time, resources and appropriate management, it is possible to re-create a number of these habitats in adjacent areas.

Prospects for reconstructing dry heathland depend on the use to which the land has been put. It has been observed that:

- heathland regeneration can be fairly rapid after removal of pine forest because the soil remains acid and the seed bank of heather plants can remain viable beneath the trees for as much as 70 years;
- deciduous woodland is less favourable because the leaf fall leads to enrichment of organic compounds within the soil to the extent that it is no longer suitable for a lowland heath flora. It would be difficult to adjust the soil to compensate for the consequent change in chemistry and organic composition;
conversion of heathland to pasture and arable farming commonly resulted in poor quality farmland, where the heather seed bank still exists within the soil. Recovery can therefore be induced fairly readily whether by allowing slow natural regeneration or by intervening more proactively. However, after about 12-15 years of natural regeneration a mixed heather and grassland community develops. This is regarded as a rare community attractive to many heathland invertebrates which should be retained in its own right; and

where existing soils have been removed, for example at mineral workings or landfill sites, soil replacement may be required. If the original soils were lifted and stored carefully the composition will remain broadly similar and heathland plant seeds may survive. If handling and replacement of the soil is undertaken with care, regeneration should be achievable. If the soils have not been retained then local sands can be used as soil-forming materials rather than bringing in soils from elsewhere. However, appropriate seeds would then need to be supplied or collected from nearby heathland. It is important to avoid using additives, such as fertilisers, since heathland plant communities require nutrient deficient soils. However, the main reason for not increasing soil fertility is to discourage invasive and aggressive fast-growing species which would dominate and exclude the slow growing heather.

A major difficulty in establishing dry heathland is that, whilst dwarf shrubs grow relatively easily, insects from an adjacent area need to colonise the site as soon as possible so that they can disperse seeds and pollinate flowers. This colonisation by both flora and fauna may be difficult, or slow. Even so, heathland has re-established in about 10 years at Masters Pit, a sand and gravel site in the west of the Wareham Basin (Plate 5). Management to retain heathland will be required. Difficulties may also occur if the site is left with an inappropriate topography, for instance a conventional up-domed restoration surface of a landfill site. There is a substantial body of information on restoration of dry heathland but the information is widely dispersed through the scientific literature and is readily available and meaningful only to specialists. There is a need to compile good practice guidance in a form that can be used by all those involved in heathland restoration.

Despite the difficulties in re-creating dry heathland, it is generally less complicated than re-creating wet heathland. Wet heathland has greater botanical diversity and successful re-creation requires the provision and maintenance of particular and subtle variations in ground conditions which depend on the interaction of landform.

It is recommended that a good practice guide for rehabilitation of lowland dry heath should be prepared as soon as possible.

Plate 5 Recent restoration to dry heathland at a completed landfill site adjacent to Masters Pit, Stokeford Heath.

It is recommended that research, including trials, on restoration of wet heathland should be set up as soon as possible and should be monitored for an appropriate period.
geology, hydrology and water quality. Attempts to recreate wet heathland have been limited, but generally successful, although uncertainty exists in the application of the same procedures to other and larger sites. There would be a considerable challenge in trying to establish the whole sequence from dry heath, through humid and wet heath to valley mire.

In terms of other land uses for former mineral workings, pine woodland can be established fairly quickly. Restoration to deciduous woodland to achieve a high level of conservation value could, however, take a very long time, in the order of 200 years or more for an oak wood. Sites worked below the groundwater level and left unfilled can provide wetland and standing water areas within which reed beds, and other habitats, will then regenerate naturally. Although some plant species may be established within the first few (5) years, development of a characteristic plant community may take up to 20 years. There is a need, therefore, to set restoration and management objectives for periods of at least 20 years.
The quality of surface and underground water in the Wareham Basin is generally high, although small streams and standing water on sand and gravel will be acidic and turbid. Consistent flow and quality is an important factor for maintaining heathland and mires that are very sensitive to changes in quality and quantity of water. Clay beds retain shallow perched water tables whilst sands are permeable and often freer draining. This gives rise to a patchwork of habitats with dry heath tending to occur on the sands and wet heath and mires on the clays. Caution is needed when:

- de-watering mineral excavations so that the hydrogeological conditions nearby are not adversely affected;
- discharging water from excavations or from processing plants since suspended solids, especially fine clay particles, can significantly reduce water quality. Where water is of adequate quality, there can be advantages in discharging it to nearby areas that are suffering water loss. Suspended particles can be dealt with by directing the water into long-term storage lagoons – an approach used at many mineral workings (Plate 6). Water can be treated chemically to cause the particles to aggregate together and settle out (flocculate). However, that may not be desirable in an area which has very high water quality because of the chemically altered discharge;
- infilling workings during restoration since there is potential for interrupting flows of water from perched water tables with consequent effects on the nearby environment.

These are all issues that can be addressed through careful operation and monitoring of a mineral site.

Much attention is, rightly, paid to protecting the water environment. However, less information is available on the management of surface and groundwater conditions during site restoration in order to support a variety of habitats within the same scheme.
The Wareham Basin contains a variety of clays, including important deposits of ball clay. Ball clay has special properties and is used in the manufacture of high quality ceramics. Common clay is suitable for the manufacture of structural ceramics, such as bricks, pipes and tiles. Ball clay extraction is an important industry, but extraction of common clay is of only minor importance and is not discussed further.

Production of ball clay

The occurrence of ball clay in the UK is confined to three relatively small areas, all in the South West Region of England. These are the Bovey and Petrockstowe basins in Devon, and the Wareham Basin (Figure 5). Demand for ball clay continues to grow. UK sales were just over 1 million tonnes in 2000 with an estimated value of about £50 million. About 83 per cent of total UK sales is exported mainly to countries within the European Union, notably Spain and Italy. Home sales help to underpin the UK whiteware ceramics industry, which had total sales of about £900 million in 1999. About 20 per cent of current UK ball clay production is from the Wareham Basin (Figure 6), of which some 83 per cent is exported.

Uses of ball clay

Ball clays are fine-grained, highly plastic kaolinitic sedimentary clays, which produce a light or near-white colour when the clays are fired. Dorset ball clays are particularly noted for their high plasticity and strength. Normally sedimentary clays fire to a reddish colour. It is this combination of plasticity and light-firing prop-
erties that make ball clays economically important for the manufacture of white-ware ceramics. When used in a ceramic body ball clay acts as a binding agent for the non-plastic components (silica sand, fluxes and ceramic scrap), allowing the pre-fired product to be shaped and handled safely between forming, drying and firing, and also contributing to the strength of the fired ware. About 76 per cent of the clays from Dorset are used in wall and floor tiles. The remainder goes for tableware, sanitaryware, electrical porcelain and refractories.

**Composition and processing of ball clay**

Dorset ball clays consist of natural mixtures of three main minerals and each in very finely divided form:

- kaolinite – a clay mineral. The kaolinite is of the highly disordered, plastic variety and is the key component of ball clay. The best clays should have a high proportion of kaolinite and at least 30 per cent in an economic ball clay;
- quartz grains – essentially very fine silt. Most commercial clays contain less than 30 per cent quartz; and
- a micaceous mineral – a clay mineral, which acts as a strong flux in a ceramic body\(^1\).

\(^1\) A ‘body’ is the term used by ceramists to describe the final mass that will be subject to the forming, decoration and firing process to yield the desired ceramic article. Whiteware ceramic bodies consist of four components: ball clay, china clay (kaolin), a flux (to lower the vitrification temperature of the body) and an inorganic filler/extender. The relative proportions and quality of each component varies widely according to the type of fabrication.
Each mineral contributes different properties to the clay and ultimately, therefore, to a ceramic body. In addition, minor components may be present that affect the quality of the clay. These are:

- iron and titanium oxides – which affect the fired colour of the product. Less than 3 per cent should be present for the light to white-firing products preferred by customers.
- carbonaceous matter – which affects the rate at which a product can be fired. Modern fast-firing kilns require that there should be less than 0.3 per cent carbon present.

Modern ceramic manufacturing methods, including automation and fast-firing, demand feedstocks with consistent and predictable properties, made up to specifications with very limited tolerances. Ball clays must, therefore, be produced to precise specifications. This is achieved by selective extraction, and shredding (Plate 8) and blending, which not only reduces the natural variations in clays extracted from the ground, but also allows the desirable properties of two or more clays to be combined. This creates a combination of properties that would not naturally occur in a single clay. Currently, some 26 ‘production clays’ are extracted in Dorset and used to make 24 saleable ‘blends’ or products. There is an average of four production clays in each blend. In practice, higher quality clays are blended with those of lower quality to meet the desired specification. While this has the advantage of maximising resource potential, there must also be access to adequate supplies of both higher and lower quality clays. Therefore, a number of pits are in operation at any time.

**Distribution of ball clays within the Wareham Basin**

Ball clays occur in four main ‘host’ clays in the Poole Formation which are interbedded with sand units in the central and eastern parts of the Wareham Basin. In ascending sequence these are known as the Creekmoor, Oakdale, Broadstone, and Parkstone clays. Their extent is shown in Figure 7 and their characteristics and economic importance of each of these are summarised in Table 1.

The host clays may be absent in some places but thick nearby. Because of excessive amounts of silica, iron oxides and/or carbonaceous matter, only parts of the host clays are of sufficient quality to be regarded as ball clays. The presence of a host clay is, therefore, not a guarantee that it will contain workable ball clay. Commercial ball clays commonly occur in the upper parts of host clays but the overall proportion of ball clay within any host clay is rarely more than 25 per cent (Plates 9-11). As many as six different qualities of ball clay may be extracted from a single host clay. This variability reflects environmental conditions at the time when the clays were deposited (Annex A).
In very general terms, there is a decrease in the proportions of good quality clays to the north of the River Frome and particularly towards the north-east of the Basin. Some of these poorer quality clays may be suitable for use in brick, pipe or tile manufacture but this is no longer an important industry in the area.

Major environmental constraints on ball clay extraction

A number of landscape, environmental and heritage constraints affect the prospects for the extraction of ball clay. About 70 per cent of production, for example, comes from within the Dorset AONB and a number of pits are close to nature conservation sites (e.g SACs, SPAs and SSSIs) (Figure 8). Whilst it is desirable to consider the extent of ball clay resources in relation to designated areas, that can only be done in detail on a site by site basis where detailed resource information is available. However, it is possible to get a general idea of the extent of the problem by comparing the overall extent of the host clays with that of designations (Figure 8). Table 2 provides the results of such an evaluation for each of the host clays.

Therefore, in general:

- higher quality host clays have limited outcrops and are extensively constrained by landscape and conservation designations. This is particularly the case for the highest quality Creekmoor Clay, which has 84 per cent of its surface outcrop within the AONB; and
- lower quality host clays are more widespread, but extensive areas of these are similarly constrained.

Some important issues for consideration are, therefore, whether:
it should be accepted that there are very limited opportunities for additional, unconstrained sites to be found when current sites containing high quality clays are depleted. This implies that subsequent supplies will have to come, substantially, from elsewhere; or

• new sites for ball clay extraction of the appropriate range of qualities can continue to be identified in the Wareham Basin by addressing and overcoming issues relating to landscape and nature conservation designations.

Policies for ball clay in the Dorset Minerals Local Plan

Current local planning policy for the extraction of ball clay is contained in the Dorset Minerals and Waste Local Plan, which has been adopted by both Dorset County Council and Poole Borough Council. The policies aim, in general, to secure, in the longer term, a shift of ball clay extraction from the Dorset AONB into the area north of the River Frome. In the interim, provision is made through identification of Preferred Areas for extensions to some existing sites within the AONB. The plan also encourages the industry to maximise the use of resources outside the AONB by finding ways to improve lower quality clays and to reduce specifications for clay. To support this objective an area to the north of the AONB has been allocated as an Area of Search in which ball clay exploration and extraction would be broadly supported. The Plan also emphasises the need to use high quality clays for high quality uses. The Plan, therefore, requires consideration of the extent to which new areas might be developed for ball clay extraction without unacceptable environmental impacts.

Alternative sources of ball clay

High quality ball clays have a restricted distribution, both nationally and internationally and the UK is a leading world producer and exporter. Alternative resources of ball clay in the UK are located only in two small areas of Devon. The Bovey Basin accounts for about 58 per cent of annual sales of ball clay. It still contains substantial unworked resources but these are also constrained by a range of national, county, dis-
strict and local conservation issues. The Petrockstowe Basin in North Devon is the smallest of the three resource areas, has the smallest output and is the least well connected in terms of transport. A decline or cessation of extraction of ball clay in the Wareham Basin might cause more pressure for release of land in Devon, particularly in the Bovey Basin. However, the characteristics of the clays are markedly different in each basin and as the availability of particular grades in demand may be limited, the potential for substitution may be highly constrained. For example, the high plasticity and low carbon content of the Dorset clays means that clays from the Bovey Basin could not easily substitute for them. There might be some increase in use of clays from the Petrockstowe Basin but these are generally more carbonaceous. A decline in production in Dorset would also cause some local decrease in employment, which might be marginally offset in Devon if substitution was possible. However, ball clay resources in Devon are increasingly also subject to environmental constraints. There is likely to be a point, therefore, at sometime in the future, when it is no longer possible to identify environmentally acceptable sites for the extraction of ball clay in the UK.

High-quality ceramic ball, or plastic clays as they are more commonly referred to overseas, are a relatively scarce resource globally. This is a function of the unusual combination of geological factors that are required for their formation and subsequent preservation from erosion and contamination (see Annex A). The highest quality deposits are located in the Kentucky-Tennessee region of the USA, in eastern, central and western Europe (Ukraine, Czech Republic, Germany, France, Portugal and Spain) and South East Asia and the Far East (Thailand, Malaysia, Indonesia, China).

However, plastic clays from these deposits exhibit widely differing properties and are not always interchangeable. There is no figure for world ‘ball clay’ production. Germany is one of the largest producers with sales of 5.4 million tonnes in 2000. However, this includes plastic clays of widely differing quality and used in structural ceramics and they are not directly comparable with British ball clays. The USA is also a large producer with an output of 1.2 million tonnes in 1999, of which exports only accounted for 120 000 tonnes. Elsewhere production is expanding, notably to service the rapidly growing ceramics industry in the Asia-Pacific region and eastern Europe and Russia. Clays from the Ukraine compete with British ball clays particularly in the Italian, Spanish and Portuguese tile markets.

The UK is self-sufficient in ball clay and imports are small. Whilst some grades of ball clay could be secured from overseas (although this would be very difficult for sanitaryware clays) at a cost, this would adversely affect the balance of payments by reversing a strong export stream into importing the commodity. It would also affect employment in the ball clay producing areas of the UK and might also affect the viability of the UK whiteware ceramics industry, which is already facing fierce compe-
Potential for additional extraction sites in the Wareham Basin

The potential for the future supply of ball clay from the Wareham Basin has been examined in the present research. The distribution of the ball clay-bearing host clays has been mapped (Figure 4 and 7). Data from about 8 500 boreholes, mainly contributed by the ball clay industry, have been compiled and evaluated.

<table>
<thead>
<tr>
<th>Host Clay</th>
<th>Proportion within AONB</th>
<th>Proportion within European site and/or SSSI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface outcrop</td>
<td>Subsurface extent</td>
</tr>
<tr>
<td>Parkstone Clay</td>
<td>467 ha (76%)</td>
<td>301 ha (80%)</td>
</tr>
<tr>
<td>Broadstone Clay</td>
<td>2513 ha (76%)</td>
<td>2421 ha (76%)</td>
</tr>
<tr>
<td>Oakdale Clay</td>
<td>387 ha (17%)</td>
<td>653 ha (16%)</td>
</tr>
<tr>
<td>Creekmoor Clay</td>
<td>1223 ha (84%)</td>
<td>1080 ha (62%)</td>
</tr>
</tbody>
</table>

Table 2  Summary of the inter-relationship of host clays to international and national designated areas in the Wareham Basin.

It is recommended that a situation report on international trade in ball clay should be prepared and revised at appropriate intervals.

Figure 8  Host clays not constrained by SSSIs and AONB.
Many of these records were from areas where ball clay is already worked. However, 23 additional boreholes were drilled as part of the present project to examine less thoroughly investigated ground. The borehole records, supplemented by geophysical data, provide information on the extent and thickness of the clays. In addition, several thousand geochemical analyses of the clays were collated from industry records, and 149 samples from the project boreholes were analysed. These data support an assessment of the quality of the clays. It provides a reasonably good geographical coverage of information, certainly far better than was previously available. The results show that the host clays exhibit a wide range of compositions (Table 3) and cannot be considered everywhere as targets for ball clay extraction.

The results support evaluation at the resource level, which is sufficient to indicate areas where ball clay resources may occur, but is not detailed enough to prove economic reserves and to the level necessary to support a planning application. However, this evaluation is an important source of information for the planning authority and for other participants in the planning process. A more detailed description of the results of this evaluation and its limitations is given in the technical report to this Summary (Bristow et al., 2002).

Detailed analysis of the data collected for the present work permits the identification of broad trends in host clay thickness and composition, and areas that are potentially prospective for ball clay (Table 4). The data suggest that at many locations the quality of the clays is very variable.

Many of the areas identified in Table 4 are, however, heavily constrained by landscape, nature conservation and other designations. The position is summarised in Table 5 and Figure 8.

In general, therefore, there are possible ball clay resources in all four host clays that may merit further investigation. However:

- all of those in the Broadstone Clay and most of those in the Creekmoor and Parkstone clays are in the AONB and only the Oakdale Clay prospects are outside the AONB;
- other prospective areas are severely constrained or fragmented by European designations. Of the prospects outside the AONB most either underlie in part or adjoin areas designated SSSI, Ramsar, SPA, SAC or priority SAC and Scheduled Monuments which may directly or indirectly constrain development;
- occurrences of high quality Creekmoor Clay are limited to the vicinity of existing workings in the AONB. Elsewhere possible resource areas are probably of low quality;
- it is unlikely that deposits with similar quality to the Creekmoor Clay in the south of the area will be found in other host clays elsewhere in the Basin.

A major issue is, therefore, the extent to which the high quality Creekmoor Clay in the south can continue to be worked in terms of both availability of resources and the extent of constraints. Only about 13 per cent of the surface outcrop and 24 per cent of the sub-surface extent of the Creekmoor Clay occurs outside areas of

---

**Table 3 Summary of the composition of the host clays.**

<table>
<thead>
<tr>
<th>Host clay</th>
<th>SiO₂ (%)</th>
<th>Fe₂O₃ + TiO₂ (%)</th>
<th>Kaolinite (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>range</td>
<td>mean</td>
<td>range</td>
</tr>
<tr>
<td>Parkstone Clay</td>
<td>50.9 – 78.7</td>
<td>64.9</td>
<td>1.9 – 4.5</td>
</tr>
<tr>
<td>Broadstone Clay</td>
<td>41.3 – 77.0</td>
<td>60.9</td>
<td>1.9 – 9.1</td>
</tr>
<tr>
<td>Oakdale Clay</td>
<td>48.0 – 76.0</td>
<td>59.9</td>
<td>1.8 – 9.4</td>
</tr>
<tr>
<td>Creekmoor Clay</td>
<td>44.6 – 73.0</td>
<td>53.7</td>
<td>1.7 – 10.9</td>
</tr>
</tbody>
</table>

It is recommended that Mineral Planning Authorities (MPAs) in the area should use the data and its associated Geographical Information System (GIS) for minerals planning as soon as possible, and consider how it might be maintained and updated, and the extent to which it might be used by other participants in the minerals planning process.
major environmental designations and parts of these are likely to be constrained in other ways. In addition, almost all of the unconstrained Creekmoor Clay occurs in the north-east of the Basin, near Poole, where it is not suitable for use as ball clay. The options might be clarified if the industry investigated in more detail some of the potential resource areas identified in the present research. These should be discussed with the relevant MPA within the context of planning constraints and other relevant issues that may apply to them and in relation to any proposed review of Planning Guidance on the national importance of ball clay.

Underground mining

Future commercial interest in ball clay extraction in Dorset is likely to be confined to sites suitable for surface working. However, since ball clay has been mined in the past, this type of extraction also merits discussion. Underground mining of ball clay was formerly undertaken at several locations in the Wareham Basin. The last small mines closed as recently as 1999 because of health and safety issues and the high cost of this method of extraction. However, it has been suggested that underground mining could provide an alternative to more extensive disturbance of the ground surface. Most of the historical mineheads were relatively inconspicuous operations and the limited subsidence of the land surface did not significantly change the character of the landscape. However, modern mine structures would probably be more substantial and it may not be possible to extract clays from beneath or near sensitive nature conservation sites without subsidence disrupting the important groundwater regime leading to undesirable changes in vegetation cover.

Since the costs of mining are much higher than those of open pit extraction, this would leave the products uncompetitive on current world markets. Specific operational constraints are safety considerations associated with potential groundwater ingress and support of the clay bed. A minimum of 5 m of clay had to be left above and below the working level and roadway size was limited without excessive roof support. This resulted in low yields and wastage of otherwise workable clay. As mining (which was by hand held pneumatic spades) is feasible only in very thick beds, most subsurface clays are incapable of being mined because they are too thin. It has been estimated that, overall, underground extraction of ball clay takes about 32 times more person effort than open pit extraction. For these reasons, recent mining was limited to specialist grades of clay, with production totalling only about 6 000 tonnes in 1998.

<table>
<thead>
<tr>
<th>Host clay</th>
<th>Areas for possible future examination</th>
</tr>
</thead>
</table>
| Parkstone Clay| Ball clay resources occur around existing workings at:  
  • Trigon  
  • Creech                                                                                                                                                                                                                         |
| Broadstone Clay| Areas of thick host clay occur at:  
  • Hartland Moor  
  • Newton Heath  
  • New Mills Heath. There is some evidence that kaolinite content may increase to the south east of Trigon but data are limited.                                                                                      |
| Oakdale Clay  | Areas of thick clay have been identified at:  
  • Woolbsbarrow  
  • Stokeford Heath  
  • Cold Harbour, east of Trigon  
  Woolbsbarrow has resource potential and Stokeford Heath is worthy of further investigation. However, elsewhere potential is limited on the basis of clay quality. Ground to the south-west of Woolbsbarrow is poorly known but may be prospective. |
| Creekmoor Clay| Most prospects are in proximity to existing workings:  
  • North of Povington Pit  
  • Between Holme Priory, Doreys Pit and Stoborough  
  • East and west of Norden  
  In addition, three areas of thick clay beneath Oakdale Clay have been identified:  
    • Wareham Forest  
    • Wool-Bovington  
    • Bere Heath-Bloxworth.  
  However, the quality of the clays appears to be low and unlikely to be of comparable quality to occurrences of this host clay in the south of the area.                                                                 |

Table 4  Ball clay resource areas that may justify more detailed examination.
Current market assessments demonstrate, therefore, that underground mining of ball clay is not likely to prove economic again, at least in the foreseeable future. It could, however, become more attractive in the future if decreased availability of domestically produced ball clay combines with significantly increased prices on world markets. This would probably only be for the highest quality clays and in areas outside and distant from designated nature conservation sites (SPA/SACs) and which could be worked by some mechanised mining method, although suitable equipment is not currently available.

<table>
<thead>
<tr>
<th>Host Clay</th>
<th>Prospective area</th>
<th>Environmental constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkstone Clay</td>
<td>Trigon</td>
<td>Outside AONB</td>
</tr>
<tr>
<td></td>
<td>Creech</td>
<td>Within AONB</td>
</tr>
<tr>
<td>Broadstone Clay</td>
<td>Hartland Moor</td>
<td>In AONB, and SPA/SAC</td>
</tr>
<tr>
<td></td>
<td>Newton Moor</td>
<td>In AONB, adjacent to SPA/SAC</td>
</tr>
<tr>
<td></td>
<td>New Mills Heath</td>
<td>In AONB</td>
</tr>
<tr>
<td>Oakdale Clay</td>
<td>Woodsbarrow</td>
<td>Outside AONB but adjacent to and fragmented by SPA/SACs and Scheduled Monuments</td>
</tr>
<tr>
<td></td>
<td>Stokeford Heath</td>
<td>Outside AONB and largely unconstraned (a)</td>
</tr>
<tr>
<td></td>
<td>Cold Harbour and Trigon</td>
<td></td>
</tr>
<tr>
<td>Creekmoor Clay</td>
<td>North of Povington pit</td>
<td>In AONB and SPA/SACs</td>
</tr>
<tr>
<td></td>
<td>Holme Priory, Doreys pit to Stoborough</td>
<td>In AONB and fragmented by SPA/SACs and Scheduled Monuments</td>
</tr>
<tr>
<td></td>
<td>East and west of Norden</td>
<td>In AONB, partly fragmented by SPA/SACs</td>
</tr>
<tr>
<td></td>
<td>Wareham Forest</td>
<td>Outside AONB and SPA/SACs</td>
</tr>
<tr>
<td></td>
<td>Wool-Bovington</td>
<td>Outside AONB, partly fragmented by SPA/SACs</td>
</tr>
<tr>
<td></td>
<td>Bere Heath - Bloxworth</td>
<td>Outside AONB, largely unconstraned (a)</td>
</tr>
</tbody>
</table>

(a) Largely unconstrained by national designations. Other constraints may also occur.

Table 5  Environmental constraints on resource areas

It is recommended that the economic prospects for underground mining should be reviewed by the MPA and industry at intervals, perhaps linked to reviews of the Minerals Development Plan.
Blending and improvement of ball clays

The supply of ball clay is directly related to the market demand for specific qualities of saleable clays that are produced by blending higher quality and lower quality production clays in specified proportions. There is an issue, therefore, as to whether ceramic manufacturers (consumers) could be persuaded to accept different specifications so that higher proportions of lower quality clays could be used or, alternatively, whether lower quality clays could be upgraded to meet more demanding specifications.

Blending of clays already reflects customer requirements for consistent grades with reproducible characteristics and the need to maximise the use of resources. The success of blending is dependent on the availability of a wide range of clay grades. New blends are developed to meet changing consumer needs. Recently, there has been, if anything, a tightening of specifications because of the need for homogenous, consistent feedstock for modern, highly mechanised processes. It is unrealistic to think that this might change, at least in the short term. If the Dorset ball clay industry does not meet customer specifications, in terms of quality and price, then they will buy ball clays elsewhere. A significant increase in blending to utilise lower quality clays can only be achieved through the greater use of scarcer, higher quality clays, which would then become more rapidly depleted.

Since lower quality clays are characterised by excessive amounts of quartz, iron oxides and/or carbon, they could, in theory, be processed to remove part of these. However, because of the very fine-grained nature of ball clays, and Dorset clays in particular, this would be technically very difficult. It would also be an energy intensive process and produce wastes that are less easy to handle and more potentially polluting than those arising from present operations. Costs would be increased, reducing competitiveness, and environmental problems could arise. This does not seem, therefore, to be a viable option, at least in the short term.

Restoration of ball clay workings

Most ball clay pits that have been left for more than 40 years have regenerated naturally, although rates of re-colonisation have been slow, especially for wet heath and mire. However, many are now of sufficient conservation interest to be designated as SSSIs or European sites. Some of these older workings were smaller than modern pits, although the majority were just as extensive and were not subject to planned backfilling and restoration.

The modern approach to restoration of ball clay workings is to backfill using the sand and waste clay overburden excavated from the site that cannot be sold. Because of the relatively small proportion of mineral extracted for sale, compared with materials that are returned to the pit, most of the excavation can largely be filled to original ground levels. Sites are then re-vegetated and returned, under management, to a variety of uses including agriculture, forestry, and nature conservation uses including dry heathland. Restoration to dry heathland has been successful, in the main, but there has been some debate whether the results reflect, at least in the short to medium term, the full biodiversity of mature, natural heath. In addition, the long-term viability of the resulting ecosystems has not yet been proved.

There is, however, very limited experience in restoration to wet or humid heath. A trial was carried out in 1993 in which an area of wet heathland vegetation was lifted from Doreys pit and was placed at an
engineered site at Gadle Knap to reproduce similar wet conditions (Plate 14 and 15). The vegetation has responded well to the new hydrological regime and has been monitored for nine years. The trial has shown a good degree of success both in terms of increased species assemblage and diversity (Hill and Box, 1999). The long-term viability of the ecosystem still needs to be proved.

However, it needs to be recognised that, while heathland may be a primary target for habitat creation, it is not necessarily the preferred, or optimum, solution for all sites. Small isolated areas of heathland are more fragile and have less species diversity than large, contiguous areas. It may be appropriate, in some cases, to increase overall biodiversity by restoring forestry, grassland or agricultural land to heathland and to restore some mineral workings to other land uses or habitats.

If deeper, more extensive excavations for ball clay were to be made in future these might raise greater problems in terms of land take, modification of the landscape, groundwater flow, drainage and discharge. Alternatively these might also offer opportunities for more imaginative re-shaping of the land to fit with specific restoration strategies, to form integrated systems of dry heathland, wet heath, wetland and other habitats. However, it would be a challenging task requiring great attention to the creation of topography and drainage.

**Safeguarding of ball clay resources**

An important aspect of sustainable development is to safeguard mineral resources for future generations. In 1953, a Ball Clay Consultation Area was defined in the Wareham Basin (Anon, 1953). The Local Planning Authority refers planning applications within the Consultation Area to the MPA for comment. The industry is also consulted. This enables identification of those development proposals that might sterilise valuable resources to be identified at an early stage. However, no assessment of the effectiveness of the Consultation Area in achieving its objectives has been undertaken.

The Consultation Area, covers some 147 km² and extends over a major part of the Wareham Basin, including extensive areas within the AONB (Figure 9). The present study has verified the importance of the mineral resources contained within much of the Consultation Area. However, it has...
also indicated limited additional areas that may contain ball clay resources outside, and some areas of no potential within the boundaries of the Consultation Area.

The present study has also verified that the highest quality resources are likely to occur only to the south of the River Frome, within the AONB and in that part of the Basin where there is an extensive coverage of international and national nature conservation designations. Therefore, demand for the release of additional areas within the AONB will continue, even if supplies of lower quality clays can be secured from less constrained land elsewhere in the Wareham Basin. It may be possible to satisfy some of that demand without significantly affecting nature conservation interests but it is probably not possible to avoid working in the AONB. There is a need, therefore, for clear policies for each designation as to whether land subject to such designations can be released for ball clay extraction. This will require careful examination of the extent to which working of ball clay may not conflict with the purposes of the designation, or might be in the national or public interest, and the extent to which restoration of land worked for minerals, or under other land uses, might compensate by re-creating priority habitats.

It is recommended that the MPA, LPA and industry should jointly review the boundaries of the Ball Clay Consultation Area as part of the next review of the Minerals Local Plan. This may need additional information on resource potential from ground investigations.

It is recommended that the Department of Trade and Industry should take a view on the national importance of ball clay and that the DTLR should consider these issues as part of any future review of Minerals Planning Guidance Note 1 ‘General considerations and the development plan system’.

Figure 9  Ball Clay Consultation Area and Area of Search.
Deposits of sand and gravel in the Wareham Basin consist mainly of:

- beds of sand that occur both above and between the ball clay-bearing host clays; and
- sand and gravel associated with the terraces of the main rivers in the area, particularly the Frome and Piddle.

The bedrock sands occur throughout the Wareham Basin, although they are more extensive in the western part (Figure 10), and vary laterally in thickness and quality. Individual units are often 12 to 15 m thick (Plate 16), but may be thin or even absent in places. They are the main source of sand in Dorset, mainly used as construction aggregate. Much of the sand is characterised by:

- relatively fine particle sizes, having mean size ranges for individual sand units from 0.4 to 0.8 mm, with an average of close to 0.6 mm;
- being relatively even in its distribution of grain sizes; and
- a locally low iron content.

Such characteristics also make some of the sand potentially suitable for industrial use. However, the lack of nearby markets for silica (industrial) sand limits the amounts that are produced but modest quantities are
sold for glass fibre manufacture. Resources of bedrock sands are large and shortages of construction sand are unlikely in the near future. However, a significant part of the resource is subject to various constraints. Because of the fine grain size, some sites may dispose of relatively large amounts of fine waste in silt lagoons.

The sand and gravel-bearing terrace deposits, which overlie the bedrock sands and host clays, are fairly extensive (Figure 11), but often thin (2 to 3m). Substantial areas have been worked out or are already subject to planning permission for extraction. Gravel also occurs beneath the alluvium of the river flood plains, but this is unlikely to be worked because of operational and restoration difficulties. Gravel is often worked in conjunction with the underlying sands (Plate 17). Preferred Areas for future extraction are indicated in the Minerals and Waste Local Plan but, overall, limited resources of gravel remain. The re-survey undertaken as part of this work demonstrated that the terrace deposits are about 50 per cent more extensive than previously thought, perhaps indicating a greater range of extraction options for consideration. However, the majority of these deposits are thin and of poor quality, and thus of limited commercial potential.

**Plate 17** River terrace gravels overlying Poole Formation sands, Warmwell Quarry.
Joint extraction of minerals

Extraction of sand and gravel and ball clay in the Wareham Basin is normally undertaken in separate workings. However, sand is excavated in order to gain access to ball clays and, sometimes, gravel may rest above both. Therefore, in some cases, it might be possible to work more than one mineral product from a single pit, consequently reducing the amount of ground opened for extraction at any one time. Joint extraction could be more feasible if, in the future, pits of larger size were operated. These might also allow access to more than one host clay. Larger pits might, however, be more difficult to restore, but may offer opportunities to re-create a range of interlinked habitats. However, difficult groundwater problems may be encountered in deeper excavations.

Landfill

Worked out ball clay and sand and gravel operations outside of the AONB have been used for landfill. The current Local Plan strategy for waste identifies sites for landfill, although the need for landfill and other forms of waste management facility is being reviewed in the light of European and Government targets to increase levels of recovery and reduce the amounts of material going to landfill. Landfill may assist in the recreation of the landscape but may also delay land restoration. Due to the need to engineer landfill sites so as to control any pollution issues, landfill may not be suitable for the re-creation of semi-natural habitats, particularly where ground and surface water provision is essential to maintain the habitat. In such circumstances forestry or agricultural use may be more acceptable.

An integrated development strategy

This research has identified the likely extent and quality of the mineral resources within the Basin and these can be assessed against a wide range of planning constraints. Such an assessment could identify the most favourable working prospects in a manner more consistent with sustainability.

Development of a such a strategy within the framework of a wider sustainable development strategy could form the basis for mineral planning and provide broad objectives for the long term (>20 years) and more specific guidance for the near future. This could also enable an assessment, through monitoring, of the impacts of decisions and policies which may be amended, as required, in a structured, as opposed to a random manner.

The strategy would need to be broader than just the mineral issues, because the optimal choices will involve other land use or resource concerns. It will, therefore, need to provide an overarching sustainable set of objectives within which mineral, environmental and biodiversity policies, the wider development plan policies, and the strategies of agencies and interest groups can be developed and brought to fruition.

Consideration could be given to creating a wider variety of landforms during rehabilitation and using these as a framework for developing a range of inter-linked and self-sustaining habitats with consequent gains in biodiversity.
The main minerals extracted in the Wareham Basin are ball clay for the whiteware ceramics industry and sand and gravel for construction aggregates. Ball clay is of major importance to the UK ceramics industry and is a significant export. There are major environmental constraints to extraction from the principal areas of ball clay resources, especially those containing the highest quality clays. Sand and gravel resources are, in general, less constrained. Most of the principal conclusions and recommendations from this work relate, therefore, to ball clay.

The main conclusion is that additional sources of high quality ball clay in the Wareham Basin are geographically very limited, and extensive areas of these are subject to landscape and habitat designations. Because high quality clays are essential for blending with lower quality clays there will be continuing pressure for their extraction. Therefore, it is necessary to:

- establish more clearly the extent of commercial ball clay deposits in the target areas identified in this report, particularly those of high quality, and the relationships of these to areas subject to environmental designations;
- examine the extent to which extraction operations may or may not conflict with landscape, nature conservation or other designations, either individually or collectively, and the extent to which, despite conflicts, such operations might be mitigated and/or allowed in the national or public interest;
- consider to what extent and under what circumstances restoration of mineral workings and, more generally re-creation of habitats, might compensate for the environmental impacts of mineral extraction;
- consider whether there are alternatives to the release of land for extraction of high quality clays in the AONB, or in, or close to, areas of valuable habitats; and
- establish whether current approaches for safeguarding valuable ball clay resource are adequate.

If this cannot be resolved, then in the medium term (10 years), ball clay working in the area is likely to gradually decrease.

**Resources of ball clay and constraints to extraction**

a) The database and maps prepared for this research are an important source of information for consideration in planning for the supply of ball clay in the Wareham Basin. The mapping facility also forms the basis for a GIS that can be used for future minerals planning.

It is recommended that MPAs in the area should use the data and its associated GIS for minerals planning as soon as possible, and should consider how it might be maintained and updated, and the extent to which it might be used by other stakeholders in the minerals planning process.

b) The MPA should discuss the findings on the potential resource areas, from the present research, with the industry. The industry will need to consider whether it should undertake further investigations of these areas, perhaps on a staged basis, to establish whether these do contain economically significant prospects. The MPA should examine the extent to which these resource areas are constrained by environmental and heritage designations as part of the foundation for review and revision of the Minerals Development Plan.

It is recommended that the results of discussions with the industry on possible resource areas, and results of any additional ground investigations by the industry, should be taken into account in the next, and subsequent, revisions of the Minerals Development Plan.
c) Two particular issues are whether ball clay can be extracted within areas that are within, or adjacent to, the AONB and international nature conservation sites (Ramsar, SPA or SAC). The provisions of the Habitats Directive makes it clear that development can occur only if the integrity of the site is not affected; any adverse effects can be mitigated; there is no practical alternative; the development is of over-riding public interest; and that compensatory measures can be taken. Government needs to define in what circumstances, if any, these tests might be met for the extraction of ball clay, and whether provision of alternative areas of re-created heathland, or other important habitats, elsewhere might be sufficient compensation.

It is recommended that the Department of Trade and Industry should take a view on the national importance of ball clay and that the DTLR should consider these issues as part of any future review of Minerals Planning Guidance Note 1 ‘General considerations and the development plan system’.

Restoration of mineral workings and re-creation of habitats in the Wareham Basin

a) There are a number of generally successful examples of restoration of lowland heath in the Wareham Basin although it remains to be seen whether these will be viable in the longer term. There is a substantial literature on this topic but much of it is dispersed in scientific papers and is only readily available and meaningful to specialists. There is a need to compile good practice guidance in a form that can be used by all interested parties.

It is recommended that a good practice guide for rehabilitation of lowland dry heath should be prepared as soon as possible.

b) One trial has been undertaken on the trans-location of wet heath. Whilst this shows promising signs of establishment, the technique is not proven. The regeneration of wet heathland is likely to be far more complicated than creating dry heathland. Further research, including trials, is needed to develop techniques and guidance. This should be started as soon as possible because of the time needed to establish, through monitoring, whether trials are successful.

It is recommended that research, including trials, on restoration of wet heathland should be set up as soon as possible and should be monitored for an appropriate period.

Alternative approaches to securing supplies of suitable clay

a) The demand for specific grades of ball clay is led by customer requirements. In general, specifications are becoming more stringent to meet the requirements of modern ceramic manufacturing facilities, increasing the need for higher quality, light-firing clays in the various blends. However, it should not be assumed that customer preferences are immutable. There might be merit in exploring whether there is scope for developing products other than the traditional light-firing ones that might become acceptable in the market.

It is recommended that ceramic manufacturer (customer) preferences are assessed and that views are sought on whether there could be more flexibility in future ball clay requirements.

b) If supplies of high quality clays become less easy to secure then one response might be to try to improve the characteristics of lower quality clays. At present this is regarded as uneconomic. It is possible that future price trends might make this more feasible in the future. However, with current pressure on prices there is no evidence to suggest that this will happen in the foreseeable future.
The processing that would be required may give rise to wastes that might create environmental problems during disposal. Consideration would be needed on how to best deal with these problems or, alternatively, research might be required to attempt to upgrade clays in ways that had less environmental impact.

It is recommended that consideration should be given to research on methods for improving clay quality, and that the economic feasibility of upgrading clays should be re-assessed at intervals, perhaps linked to reviews of the Minerals Development Plan.

c) Underground mining of valuable clay might minimise ground surface impacts during extraction but could give rise to subsidence which could harm nature conservation interests. However, mining is difficult, costly and could only be justified for the highest quality clays. It seems unlikely that mining will be an economic prospect in the foreseeable future, even for the highest quality clays. However, the economic viability of mining might change if world prices for ball clay were to rise.

It is recommended that the economic prospects for underground mining should be reviewed by the MPA and industry at intervals, perhaps linked to reviews of the Minerals Development Plan.

d) The future of ball clay extraction in the UK depends on the relative prospects for extraction at all three ball clay resource areas: the Wareham Basin in Dorset and the Bovey and Petrockstowe basins in Devon. Whilst the present work has contributed towards the consideration of the situation and prospects in Dorset, there is no comparable resource information for Devon.

It is recommended that research should be undertaken on the sources of ball clay in Devon, using methods appropriate to each of the two deposits, so that the results from both Dorset and Devon can be used to prepare an overall sustainability analysis of ball clay extraction in the UK.

e) At present, much of the ball clay extracted in the UK is exported. There is a need to understand the international trading pattern for this commodity, and specifically for clays for different sectors of the ceramic industry, and the implications that this might have for future demand for the mineral within the UK.

It is recommended that a situation report on international trade in ball clay should be prepared and revised at appropriate intervals.

f) There might be advantage in considering whether a more integrated approach to resource development and rehabilitation might be undertaken in the Wareham Basin. Sand and gravel and ball clay have tended to be worked in separate operations. Waste clay and sand are returned to the pit during restoration. Consideration might be given to whether joint extraction might, in some cases, be feasible, and whether more complete extraction can be achieved without seriously prejudicing opportunities for site restoration. Strategies for landfill could be integrated more firmly with strategies for mineral extraction. In addition, consideration could be given to creating a range of landforms during rehabilitation and using these as a framework for developing a wide variety of inter-linked habitats with consequent gains in biodiversity.

It is recommended that possibilities for integrated resource development and rehabilitation should be considered when the relevant minerals development plans are reviewed.

Safeguarding of ball clay resources

a) A Ball Clay Consultation Area has existed in Dorset as a means of liaison between the MPA, LPA and the industry since 1953. It appears to have been generally effective in avoiding sterilisation of important mineral resources. However, the effectiveness of the arrangements has not specifically been reviewed (page 24).
b) The present study has established that some areas within the Ball Clay Consultation Area may not con-
tain ball clay, while some areas outside the Consultation Area may have potential.

It is recommended that the MPA, LPAs and industry should jointly review the boundaries of the Ball Clay Consultation Area as part of the next review of the Minerals Local Plan.

**Sand and gravel**

The Dorset Minerals and Waste Local Plan identifies Preferred Areas for sand and gravel extraction. The present research has indicated that terrace gravel is more widespread than was indicated by earlier geological surveys, although these may be of limited commercial potential. This needs to be taken into account.

It is recommended that Dorset County Council should take information from the present work into account when considering allocations during the next review of the Dorset Minerals Local Plan.
The specialised conditions and restricted geographical areas in which ball clays were deposited are now fairly well understood.

The Dorset ball clays are of the same approximate age as those in Devon, but they differ somewhat both in the origin of the clay and its depositional environment. The former were laid down under estuarine conditions rather than on flood plains or in lakes. This accounts for some of the differences in their respective properties.

Tropical to sub-tropical weathering of land surfaces consisting of mudrocks and sandstones, about 40 million years ago, gave rise to kaolinite and sand. These were eroded and carried in eastward flowing rivers to an estuarine area where the sand and clay were then deposited (Figure 12). The environmental conditions varied as time passed depending on whether marine or land influences were stronger. When sea-level was low, there was erosion and little sedimentation. As sea level rose, sands were deposited. When sea level reached a maximum, silt and clay were deposited. The clay accumulated because the minute grains aggregated together into larger particles due to chemical action (floculation) when fresh river water met saline sea water (Figure 13). These fine-grained deposits often accumulated in depressions and channels eroded into the surface of the underlying sands (Newell, 1999).

Figure 12  Palaeogeography of South-west England during the deposition of the ball clay.
When sea level fell, general erosion took place leading to the partial, or even complete, removal of a host clay, including any ball clay. Clay beds were also exposed in places and soil horizons developed. Where groundwater levels were low, oxidation occurred and the clays became mottled and discoloured mainly by oxides of iron. Where groundwater levels were high, however, the clays remained unstained and some additional micaceous minerals were altered into kaolinite, thus improving the quality of the clay (Figure 14).

This series of events was repeated four times corresponding to the four main host clays. Therefore, in general:

- due to periodical erosion, host clays are not present everywhere in the Basin;
- erosion was uneven, with deposits in deep channels being more likely to be preserved; thus ball clays may be absent or thick within a short distance;
- the thickest sediments accumulated in the south central to eastern parts of the basin where, on average, thicker host clays are found;
- downstream (eastwards), marine influence increased leading to an increase in the presence of micaceous mineral at the expense of kaolinite;
the dynamic environmental conditions at the time of deposition explain why host clays can be economic in one place but of lesser quality nearby, and vary in quality through the thickness of the bed; and

the best host clays are found where deep estuarine channels were filled in but subsequent erosion was insufficient to cause major erosion, and where oxidation and staining has not occurred.

It is this variability resulting from the dynamic conditions of deposition and erosion that makes it very difficult to extrapolate from existing information to predict where good quality clays occur. Reliance has to be placed, therefore, on detailed ground investigations. However, knowledge of the distribution of the host clays allows such investigations to be focussed.

Figure 14 Sequence of events controlling the deposition, alteration and preservation of ball clay. (A) Deposition from muddy river waters in an estuarine channel. (B) Differential uplift, possibly caused by small fault movements, subjects the ball clay to weathering which could increase the amount of kaolinite in the clay but which could also cause the development of iron oxide staining. (C) Erosion removes some of the ball clay, followed by deposition of sand.

- the dynamic environmental conditions at the time of deposition explain why host clays can be economic in one place but of lesser quality nearby, and vary in quality through the thickness of the bed; and

- the best host clays are found where deep estuarine channels were filled in but subsequent erosion was insufficient to cause major erosion, and where oxidation and staining has not occurred.

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REFERENCES


