Mineral Resources
Consultative Committee

Mineral Dossier No 16

Potash

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Titles in the series

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
No 11	Ball Clay
No 12	Slate
No 13	Gypsum and Anhydrite
No 14	Gold
No 15	Mica
No 16	Potash

Preface

The Mineral Resources Consultative Committee consisted 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 led the Committee to undertake the collation of the factual information available about those minerals (other than fossil fuels) which were 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

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British Gas Corporation
British Sulphur Corporation Limited
Charter Consolidated Limited
Cleveland Potash Limited
Fertiliser Manufacturers Association Limited
Fisons Limited (Fertilizer Division)
Imperial Chemical Industries Limited (Agricultural Division)
Potash and Continental Limited
Propane Fertilisers Limited
Rio Tinto Finance and Exploration Limited
Yorkshire Potash Limited

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

Contents

Illustrations

Summary

Potash is used in the commercial sense to denote any naturally occurring raw material, either in the solid form or as brine, which contains sufficient quantities of potassium-bearing minerals to be of economic or potential economic importance. The soluble mineral sylvine (KCl) is by far the most important commercially because of its high potassium content. Potassium salts are used chiefly as a component in the manufacture of compound fertilisers or for direct application to the soil. To a much lesser extent, they are utilised for a variety of industrial purposes, notably the manufacture of glass and such chemicals as caustic potash and potassium permanganate. The equivalent potassium oxide, K_2O, content is used as the basis of comparison for all potassium compounds.

Soluble potash salts are of restricted distribution in the United Kingdom, occurring only in the Upper Permian formations of Cleveland and North Yorkshire at depths ranging from 1,100 to 2,000 m. In Cleveland, the Boulby Potash bed is up to 11 m thick and averages more than 25 per cent equivalent K_2O. Resources are very large and reserves alone amount to at least 500 million tonnes of potash containing up to 27 per cent equivalent K_2O. There are also substantial resources of potash feldspar, an important potassium-aluminium silicate in the granitic pegmatites and the Fucoid Beds of the North-West Highlands of Scotland, and of the iron-potassium silicate, glauconite, an essential constituent of the greensand formations which are extensively developed in the Lower Cretaceous and Eocene rocks of southern England. Neither of these is commercially attractive as a source of potassium compounds, nor is sea water by virtue of its low concentration of potassium.

The United Kingdom is a major importer of potassium salts, mainly for fertiliser use. The chief sources of supply are the German Democratic Republic and the Federal Republic of Germany. About 910,000 tonnes of potassium minerals, manufactured fertilisers and industrial compounds were imported in 1974, valued at over £32 million, of which potassium chloride (muriate of potash) accounted for some 805,500 tonnes valued at nearly £27 million. Exports are relatively insignificant, amounting to some £2.3 million in 1974, chiefly in the form of potassium iodide and potassium cyanide. The Boulby mine, which started production in 1974, is nominally capable of satisfying the entire United Kingdom demand for potash in the near future and of contributing a substantial quantity for export. Production amounted to some 18,359 tonnes equivalent K_2O in 1974. The main product is a flotation concentrate containing 60 per cent equivalent K_2O.

The Boulby mine has been developed by Cleveland Potash Limited, a company owned jointly by Imperial Chemical Industries Limited and Charter Consolidated Limited. ICI Limited and Fisons Limited are the principal users of potassium salts. From Boulby, potash is carried by rail to a main terminal on Teesside for subsequent distribution to ICI's plant at Billingham and to other United Kingdom and overseas customers.

Two other companies, Whitby Potash Limited and Yorkshire Potash Limited, wholly-owned subsidiaries of Armour and Company and the Rio Tinto-Zinc Corporation Limited respectively, were formed with a view to developing potash production in the same area, but their activities are currently in abeyance following initial investigation. Together with Cleveland Potash, these companies could conceivably have raised production of marketable potash to around 3 million tonnes KCl a year.

Definition and mode of occurrence

The term potash, when used in the strict chemical sense, refers to potassium oxide, K_2O, a compound not found in nature or produced artificially, but used as the basis of comparison for all potassium compounds. It is now generally applied to any naturally occurring material, either in the solid form or as brine, which contains potassium-bearing minerals in sufficient quantity to be of commercial or potential economic importance. Originally potash referred to potassium carbonate, from the time when 'pot ashes' were produced by burning wood in retorts or pots, after which the ashes were leached in hot water and the resulting solution evaporated to dryness to obtain an impure mixture of potassium carbonate with other salts.

Potassium is widely dispersed in nature as an essential constituent of plant and animal life. It is not found in its native state because of its great affinity for other elements, particularly chlorine, the chlorides being the commonest potassium salts. Sea water contains only about 0.04 per cent equivalent K_2O, but certain enclosed basins where partial evaporation of oceanic or lake waters has taken place contain much higher concentrations. Searles Lake in California and the southern Dead Sea are striking examples. Some underground waters are markedly saline but do not contain potassium in sufficient amounts to warrant commercial extraction.

There are many potassium-bearing minerals, but only those which are water soluble are worked commercially at present, sylvine (known also as sylvite) and carnallite (Table 1) accounting for most of the world production of potash for agricultural and industrial purposes. Kainite and langbeinite are also produced in significant quantities. The potassium minerals seldom occur pure and the mined materials are invariably a physical mixture of salts. For example, *sylvinite* is a mixture of sylvine and halite (NaCl) in varying proportions. In most potash deposits halite or common salt is the principal gangue mineral.

Soluble potassium salts were first discovered in what is now the German Democratic Republic at Stassfurt in 1856, when Heinrich Rose, the Professor of Chemistry at the University of Berlin, identified a potassium - magnesium chloride (carnallite) in the 'waste-salt' from a mine developed to produce rock salt. This double salt was named Carnallit in honour of Rudolf von Carnall, adviser to the Prussian Ministry of Trade, Industry and Public Works and designer of the mine shafts. Potash and rock salt were produced from the Stassfurt mine for many years until operations ceased there in December 1972.

Sylvine, which was first discovered as a volcanic sublimate on Mount Vesuvius, is by far the most important commercial source of potash because of its high potassium content, equivalent to 63.1 per cent K_2O when pure, and its ready solubility. The mineral is colourless to white, blue or yellowish-red, brittle, with a vitreous and greasy lustre and a characteristic salty, somewhat bitter taste. It is a relatively soft mineral with a hardness of only 2 on Mohs' scale, and produces a distinct powder when scratched with a knife. It has a specific gravity of 1.98 and a perfect cubic cleavage. Under continuous pressure it yields plastically. *Carnallite* is brittle, has a greasy lustre and is colourless to white when pure, but is usually reddish-brown due to minute inclusions of orientated scales of the iron oxide mineral haematite (Fe_2O_3). It has a hardness of 2.5, a specific gravity of 1.60 and is distinguished from other potassium salts by lack of cleavage, conchoidal fracture and deliquescence in a moist atmosphere.

Table 1 Chemical composition and equivalent K_2O content of selected potassium minerals

Chemical composition		*Equivalent K_2O content per cent*
Chloride		
Sylvine	KCl	63.1
Carnallite	$KCl.MgCl_2.6H_2O$	17.0
Chloride-sulphate		
Kainite	$MgSO_4.KCl.3H_2O$	18.9
Sulphate		
Langbeinite	$K_2SO_4.2MgSO_4$	22.6
Polyhalite	$K_2SO_4.MgSO_4.2CaSO_4.2H_2O$	15.5
Nitrate		
Nitre	KNO_3	46.5
Silicates		
Orthoclase	$KAl\ Si_3O_8$	16.8
Muscovite	$H_2KAl_3(SiO_4)_3$	11.8
Glauconite	$KFe\ Si_2O_6.nH_2O$	2.3 - 8.5

Kainite is colourless or white to dark red, has a vitreous lustre, a hardness of 3 and a specific gravity of 2.13. It is not deliquescent but dissolves readily in water. After gypsum and anhydrite, *polyhalite* is the most abundant sulphate mineral in marine evaporites. This mineral has a dull lustre, ranging in colour from white to brick red. It is normally opaque, massive, with a conchoidal fracture, having a hardness of 3 and a specific gravity of 2.8. It can be distinguished from anhydrite by the white coating of gypsum which develops after wetting and drying. Like polyhalite, *langbeinite* is only slightly soluble in water. It is brittle, with a hardness of 4, similar to that of compact limestone. It is colourless or grey and has a specific gravity of 2.8. Other properties include a vitreous lustre, conchoidal fracture and lack of taste. *Nitre* and saltpetre are alternative names for potassium nitrate which occurs in nature chiefly in conjunction with the sodium (or Chilean) nitrate deposits on the eastern part of the Chilean coastal range.

A number of insoluble potassium-bearing aluminium silicates are among the common minerals in sedimentary and igneous rocks. *Orthoclase* is a characteristic potash feldspar of some igneous rocks, and its variety *Adularia* is an important constituent of some shales. Crystals of orthoclase, normally white, cream or pink in colour, are usually short prismatic in habit and show a perfect basal cleavage. The mineral has a white streak, vitreous lustre, a hardness of 6 and a specific gravity of 2.56. The potash feldspar of practically all granite pegmatites and veins is *microcline,* which can be distinguished easily from orthoclase only by its optical properties. *Muscovite* is a transparent silicate colourless when pure but usually tinted green, grey or brown with impurities, which occurs commonly in granites, granite pegmatites and many metamorphic rocks as lamellar masses or small flakes. The perfect cleavage and flexible, elastic laminae are diagnostic features of the mineral, which has a hardness of 2.5 and 4 on and across the cleavage planes respectively, and a specific gravity of 2.8-2.9. Feldspar and other potassium-bearing silicates are also present in small quantities in porphyry copper tailings, blast-furnace and Portland cement flue dusts. *Glauconite,* another silicate, characteristically occurs as small green to black granules in marine sedimentary rocks. The mineral has an earthy and dull lustre, a hardness of 2 and specific gravity of 2.5-2.8. It is an essential constituent of *greensand*, beds of which are well developed in the Lower Cretaceous and Eocene rocks of southern England.

Origin

The extensive stratified potash deposits of commercial importance in various parts of the world are generally considered to have been produced by the evaporation of sea water under arid conditions in basins whose configuration is such that, although they are separated from the open ocean, a continuous or periodic influx of new sea water occurs to replace the loss by evaporation. Under ideal conditions the principal mineral phases formed as evaporation proceeds are, in order, calcium and magnesium carbonates (calcite and dolomite), calcium sulphate (gypsum and anhydrite), gypsum with halite, and finally the very soluble sulphates and chlorides of magnesium and potassium. Many evaporite sequences show at least the earlier part of the expected succession. In some, cyclic, but not always complete, sequences have been recognised, the presence of potassium salts perhaps reflecting temporary isolation of the basins of deposition and almost complete desiccation. This theory of origin for evaporite deposits is not, however, entirely unchallenged. An alternative mechanism for the origin of the potash deposits in Cleveland and North Yorkshire, for example, is the emplacement of salts in coastal sediments of intertidal and supratidal origin after burial, a view modified by the suggestion that the potash salts could also have been formed either as primary chemical precipitates from marine groundwaters or by early diagenetic replacements of existing minerals in extensive coastal salt flats or ‘sabkhas’. The mode of formation envisaged is based on a long, gradual concentration of potassium and magnesium salts by repeated precipitation and solution resulting from the periodic flooding of extensive coastal salt flats. The processes are akin to those operating on modern salt flats.

The mineralogy of most evaporite beds has been complicated by extensive post-depositional changes involving various transformations and replacements, some of which are complex. In the Cleveland and North Yorkshire potash beds, for example, few of the original minerals have survived. Sylvine is probably derived largely from carnallite-halite rock, but in part may also be of primary origin. Most carnallite is primary and polyhalite, most of which is secondary, forms thick deposits in association with anhydrite and halite. Langbeinite and kainite are commercially important constituents of the potash deposits of New Mexico (USA) and the Federal Republic of Germany respectively. Langbeinite may be primary or secondary and kainite occurs largely as a secondary mineral following the leaching of potash beds by meteoric waters. In some of the Permian evaporites of north-east England five generations of carnallite, sylvine and anhydrite, and four of halite, have been recorded.

Resources

Soluble potassium salts were first discovered in the United Kingdom in North Yorkshire in a borehole drilled for oil in 1939 by the D'Arcy Exploration Company (a subsidiary of the former Anglo-Iranian Oil Company Limited) near Aislaby, about 5 km south-west of Whitby. Further investigations carried out by Imperial Chemical Industries Limited and Fisons Limited near Whitby and Robin Hood's Bay between 1948 and 1952, as well as detailed logging by the Institute of Geological Sciences, have revealed the presence of three main groups of evaporites in Cleveland and North Yorkshire at depths ranging from about 1,100 to 2,000 m. These groups, which include extensive beds of anhydrite, are the Fordon (formerly Lower) Evaporites, the Boulby (formerly Middle) Halite and the Upper Halite (Fig 1), all of which were deposited in Upper Permian times within the Zechstein Sea. This sea may originally have covered an area of about 1,040,000 km^2.

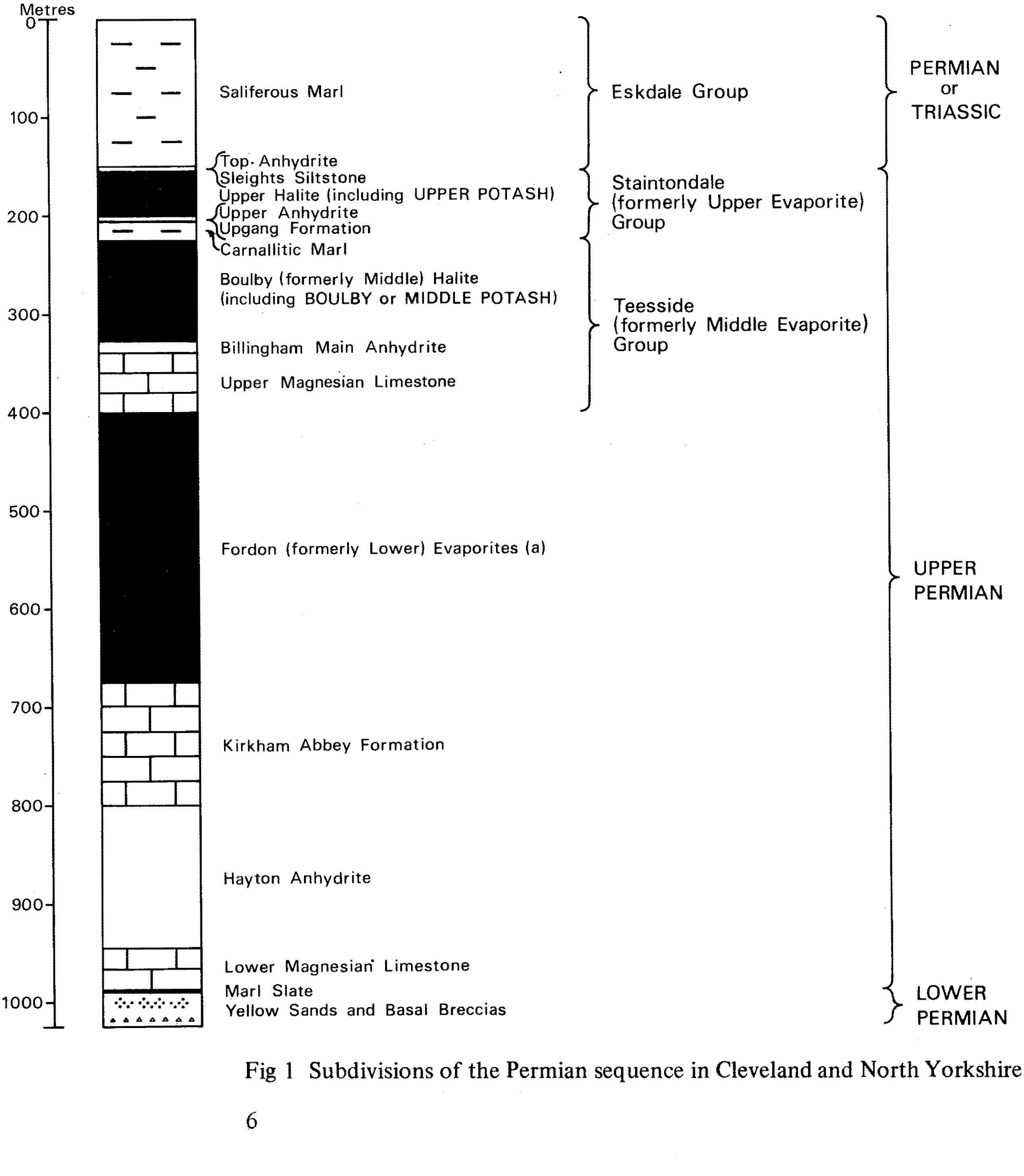

Fig 1 Subdivisions of the Permian sequence in Cleveland and North Yorkshire

Potash deposits in the Fordon Evaporites are represented mainly by polyhalite, and sylvine is the principal potassium salt in both the Boulby and Upper Potash beds. The Boulby Potash is a variable stratiform deposit 7 m thick at the Boulby mine, where the mined section averages more than 25 per cent equivalent K_2O; in the Whitby area grades ranging from 21 to 45 per cent KCl (13 to 27 per cent equivalent K_2O) have been recorded in five boreholes, while at Sleights the grades range from 10 to 45 per cent KCl (6 to 28 per cent equivalent K_2O). The Upper Potash is up to 8.5 m thick and, although the bed does not extend as far west as the Boulby Potash, it is less variable in character and thickness. The bed contains up to 26 per cent KCl (16 per cent equivalent K_2O) at Staintondale. Available geological evidence indicates that both the Boulby and Upper Potash deposits in Cleveland and North Yorkshire were formed relatively close to the western margin of the English Zechstein Basin, the Upper Potash probably having been deposited somewhat nearer the centre of the basin (Fig 2). In addition to mixtures of sylvine and halite (as sylvinite) the Boulby and Upper Potash beds generally contain subordinate amounts of anhydrite, carnallite, quartz, magnesite, talc, clay minerals, haematite and the magnesium borate mineral boracite.

In the Boulby area near Staithes, where the Boulby Potash beds are reached at a depth of 1,070 m, deposits proved by drilling 15 boreholes between 1965 and 1968 have been found to be relatively free of faulting and of comparatively high grade. The evaporites in the area consist of some 43 m of Upper Halite underlain by nearly 9 m of anhydrite and 11 m of marl, often called the ‘rotten marl’ or ‘Carnallitic Marl’, which is a weak mudstone with a high halite content. Both the marl and the anhydrite beds contain abundant veins and lenses of sylvinite. At Boulby the potash bed is underlain by the Boulby Halite, through which the mine shafts have been sunk to the Billingham Main Anhydrite.

Total resources of potash in Cleveland and North Yorkshire are very large, with reserves amounting to over 500 million tonnes KCl on the basis of exploratory drilling carried out to date. The investigations by ICI Limited and Fisons Limited shortly after the Second World War within a roughly circular area of about 31 km^2 south-west of Whitby bounded by Aislaby, Eskdalegate, Sneaton and Upgang, indicated reserves totalling some 216.5 million tonnes KCl, of which 64.5 million tonnes KCl is in the Upper Potash bed, assuming a thickness of 6 m and a KCl content averaging 17 per cent (10 per cent equivalent K_2O). A further 152 million tonnes KCl was indicated in the Boulby Potash, which averages about 7 m in thickness and contains up to 32 per cent KCl (19 per cent equivalent K_2O). Reserves of potash in the polyhalite-bearing Fordon Evaporites have not been calculated.

Within the area of some 78 km^2 held by Cleveland Potash Limited near Staithes (Fig 3), proved reserves containing more than 25 per cent equivalent K_2O are said by the company to be capable of supporting economic mining operations for 20 to 30 years, and are placed at 50 million tonnes with an extraction rate of 35 per cent. In an adjoining area investigated by Whitby Potash Limited covering some 50 km^2 and extending from Lealholm to Sneaton, reserves of at least 22.5 million tonnes of high grade potash ore, averaging about 28 per cent equivalent K_2O, are conservatively estimated to be present, equivalent to about 11 million tonnes KCl, and within an area of 30 km^2 between Robin Hood’s Bay and Whitby explored by a third company Yorkshire Potash Limited, anticipated reserves in the Boulby Potash, both on land and offshore, have been calculated at 380 million tonnes, assuming an average mineable thickness of 3.7 m grading 23 per cent equivalent K_2O.

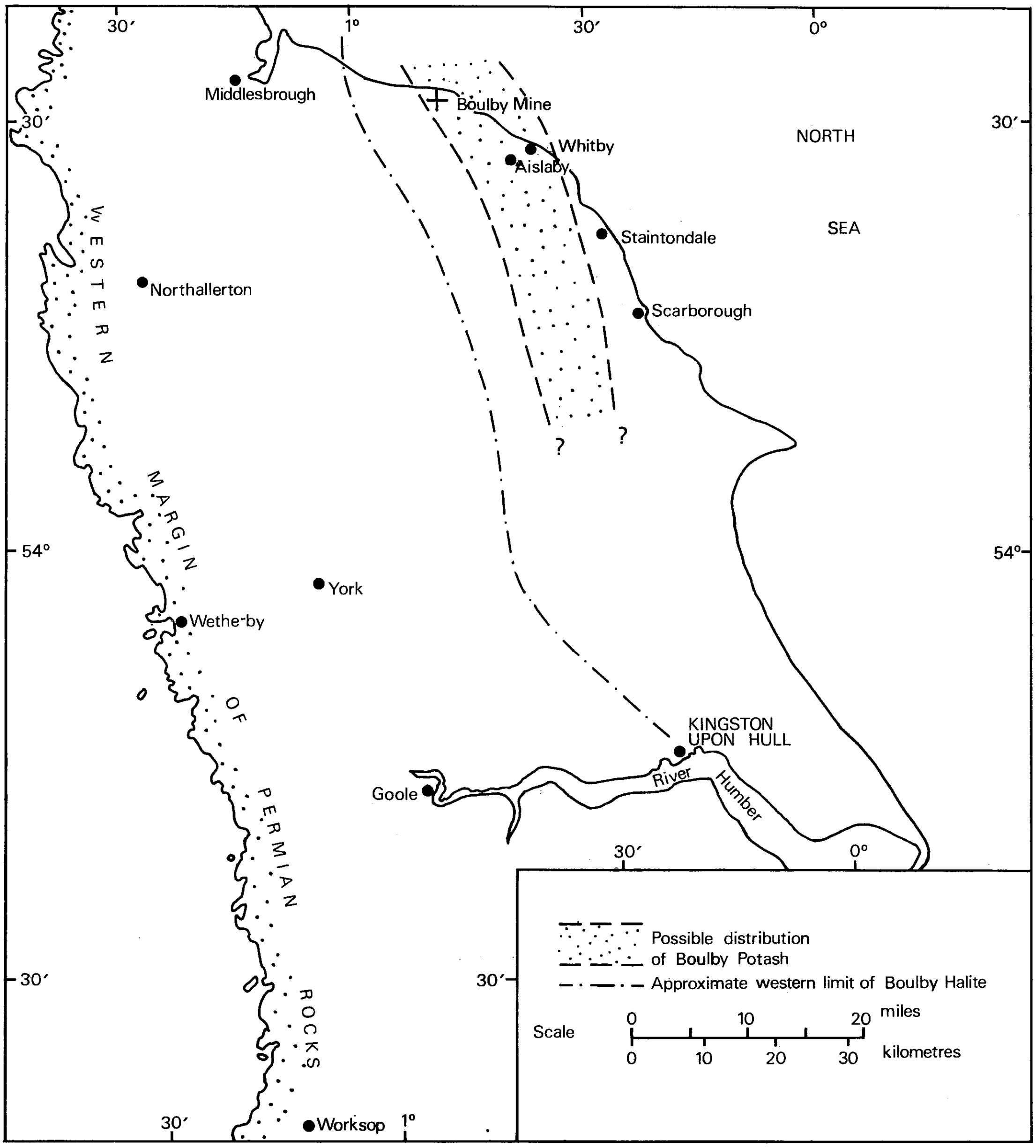

Fig 2 Approximate extent of Permian potash beds in Cleveland and Yorkshire. (Based on D.B. Smith. *The Geology and Mineral Resources of Yorkshire, 1974.)*

Continental Shelf

Geological data available on the Permian potassium-bearing sediments of north-eastern England suggest that these were deposited near the western margin of a broad basin which occupied most of the area of the present North Sea. Permian potash deposits are therefore likely to occur extensively off the coast of Cleveland and North Yorkshire, principally those of the Boulby and Upper Potash beds. Significant tonnages of potash ore may be present offshore between Robin Hood's Bay and Saltburn-by-the-Sea, including some 185 million tonnes between Whitby and Robin Hood's Bay.

Permian evaporites are widely distributed under the southern North Sea, where rock salt (halite) occurs in various structures including large diapiric salt plugs. Near the coast of Cleveland and North Yorkshire and off Norfolk, studies carried out on behalf of the British Petroleum Company Limited and the British Gas Corporation have shown that potassium salts occur in a zone

5 to 15 m thick near the top of the Boulby Halite, separated by up to 3 m of halite from the overlying Carnallitic Marl. Over a large part of the southern North Sea Basin, a thick sequence composed of halite, potassium-salts (probably carnallite and polyhalite) and possibly mudstone has been established in the upper part of the Teesside Group. In addition, a widespread bed of carnallite or sylvine up to 10 m thick occurs near the top of the Fordon Evaporites. The presence of Devonian evaporites beneath the North Sea between Scotland and Norway has also been postulated.

Sea water

Sea water is a very large potential source of potassium compounds, although its low concentration of potassium, averaging about 0.04 per cent equivalent K_2O, makes it commercially unattractive while very large potash reserves are available on land. Another possibility is the recovery of potassium compounds from desalination plant effluent, which contains about 0.1 per cent equivalent K_2O. However, none of the processes studied has been proved on a commercial scale. A desalination process was developed by the Water Research Association in collaboration with the United Kingdom Atomic Energy Authority during the 1960s but a project to build a large plant on the Deben estuary east of Ipswich in Essex was abandoned in 1972.

Other resources

Other sources of potash occur in the United Kingdom but these are unlikely to be of economic interest while large workable deposits of soluble potassium salts are available in Cleveland.

Potash feldspar is widely distributed in shales and pegmatites in the North-West Highlands of Scotland. In Sutherland and on South Harris in the Outer Hebrides, for example, pegmatite veins locally swell to a width of 6 or 9 m or more and probably average 7 per cent equivalent K_2O. In the North-West Highlands, the potassium-rich nature of shales and dolomitic shales of the Lower Cambrian Fucoid Beds was discovered by the Geological Survey of Great Britain in 1959 during a geochemical study of British shales. The Fucoid Beds outcrop intermittently between Loch Eriboll in Sutherland, Loch Kishorn in Ross and Cromarty and again in southern Skye, a total strike distance of about 177 km, and where undisturbed dip eastwards at 10 to 20^{o}. The beds are estimated to range in thickness from 12 to 27 m; at Loch Awe, about 6 km south of Inchnadamph, the average equivalent K_2O content over a thickness of about 12.5 m is 9.3 per cent. One bed at this locality contains 12.3 per cent K_2O. The principal potassium-bearing mineral in the Fucoid Beds is fine-grained orthoclase, associated usually with small amounts of muscovite, biotite, glauconite, dolomite and quartz. Haematite and pyrite are the most common minor constituents. On the basis of a preliminary assessment, it has been suggested that tens of million tonnes of rock averaging 8 per cent equivalent K_2O are present.

Investigations carried out by the Geological Survey in south-eastern England during the Second World War drew attention to the presence of significant tonnages of greensand containing more than 50 per cent glauconite in the Eocene Blacklesham Beds in the London Basin. It has been estimated that along 32 km of the 160 km outcrop resources may amount to about 7 million tonnes of greensand, assuming an average thickness of some 2.4 m and a maximum overburden of 3.7 m. The most suitable deposits for development were considered to be at Knaphill and Chobham Common in Surrey and at Hazeley Heath in Hampshire. Analysis of an average sample of greensand from a bed about 2 m thick at Knaphill gave 4.8 per cent equivalent K_2O. None of the Lower Cretaceous greensand beds in southern England was considered promising as a commercial source of potash.

Glauconite beds occur also in Northern Ireland in the Hibernian Greensand of Upper Cretaceous age preserved in the Belfast area and on the east coast. An unsuccessful search for potash in the saliferous strata of Triassic age which occur beneath Belfast Lough from Carrickfergus to Larne has been made by the Geological Survey of Northern Ireland.

Land use

Planning applications from three companies for the development of potash deposits in Cleveland and North Yorkshire were referred for decision to the then Minister of Housing and Local Government, in accordance with a direction made under Section 15 of the Town and Country Planning Act, 1947.

The first, received from Cleveland Potash Limited, was the subject of a public inquiry at Northallerton in August, 1968, and permission was granted in November of that year. It relates to an area of about 75 km^2 (Fig 3) extending along the coast for some 2 km east of Saltburn-by-the-Sea to the western side of Runswick Bay, a distance of about 13 km, and inland for between 5 and 8 km on to the moorlands of the south. Most of the area is rural, about two thirds lying within the North York Moors National Park. The minehead site, east of Loftus beside the A174 road at Old Boulby, has an area of some 72 hectares and is nearly 2 km inside the National Park. Use of the site for potash production will sterilise land for other use and steps have been taken by the operating company to minimise disturbance to rural amenity. In general, it has been concluded that subsidence of the surface and damage arising from it are unlikely to occur as a result of potash mining, bearing in mind the considerable working depth and the nature of the overlying strata which contain a high proportion of competent beds. Some 70-75 per cent (on an area basis) of the potash bed is to be left *in situ* in pillars and it is proposed to reduce the percentage extraction even more under certain built-up areas where previously there had been subsidences due to nearby old ironstone workings. Problems related to possible plastic flow of the pillars at the mining depths involved have also been investigated.

Public inquiries were held in Whitby in April and May 1969 to consider applications from the two other prospective potash producers, Yorkshire Potash Limited and Whitby Potash Limited. Permissions were granted in May 1970 but both companies subsequently announced their intention not to proceed with their projects in the short term. Both permissions were subject to conditions requiring the companies to agree details of plant and building with the County Council within five years, and to commence operations within seven years, of the date of the planning permission. In 1975, both companies applied to the North Yorkshire County Council for permission to extend the 5-year period for agreement of details.

The application of Yorkshire Potash Limited covered an area of about 29 km^2 along the coast from Whitby for about 8 km southwestwards and up to about 6 km in an east-west direction. Most of the area lies within the North York Moors National Park. The proposed minehead site, covering an area of 36 hectares, is situated mainly in farmland at Hawsker Bottoms, nearly 5 km south-east of Whitby and 2.5 km inside the National Park.

The proposals by Whitby Potash Limited to extract potash by solution mining centred on the construction of well-head cluster sites each containing four wells, on Barnby Moor to the north of the A171 and Egton Low Moor to the south of the road. All the wells were to be situated towards the western end of an application area of about 30 km^2 bounded by Lealholm, Mickleby, Egton, Ruswarp and Ugglebarnby Moor. The greater part of the

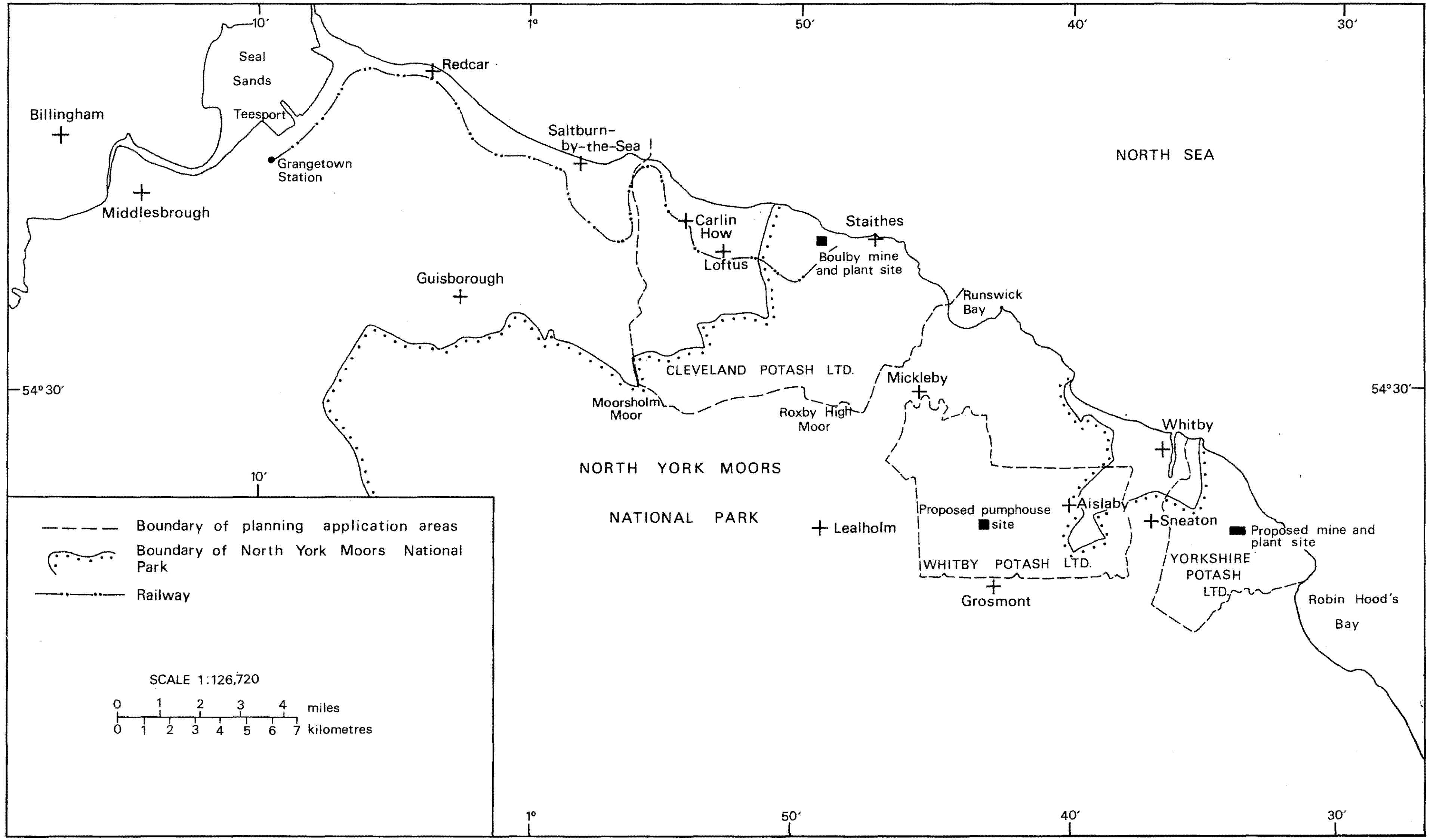

Fig 3 Potash planning permission areas, Cleveland and North Yorkshire

property lies within the North York Moors National Park. The proposed pumphouse site lies just east of the 5 cluster sites on Egton Low Moor, close to the pilot plant site (now restored) operated by the company between 1966 and 1969. The proposed refinery site, which is situated on the outskirts of Whitby about 1 km south-east of the town centre outside the mining application area, has an area of some 34 hectares. Production was planned at an expected rate of 450,000 tonnes of marketable potassium chloride a year apparently involving little risk of noticeable surface subsidence. It was estimated that the life of each cluster of boreholes would be about 8 years.

Environmental considerations

The working of mineral deposits in the National Parks of the United Kingdom is a question which has raised considerable controversy in recent years. At the Boulby mine site, special attention has been paid to layout as well as to the design of such structures as the refinery, the crude ore and product storage sheds and the shaft headgear. The ore shaft headgear is 54 m high; that of the service shaft 33 m. Gaseous effluent arising chiefly from the boiler plant and the main drying operations is dispersed from stacks 86 m high, although air pollution is not normally regarded as a serious problem for potash producers.

The Boulby refinery will require a supply of about 19 million litres of sea water a day at the proposed rate of throughput, the tailings being slurried and pumped along a specially constructed tunnel beneath the sea bed to a discharge point about 1.6 km from the shore. The effluent would probably amount to 21.6 million litres per day, comprising (by weight) 79 per cent sea water, 16 per cent common salt and potassium chloride, about 2 per cent anhydrite, about 2 per cent of insoluble sand and clay and less than 1 per cent of carbonates and iron oxide. In addition, there would be trace amounts of chemicals used in the flotation process. It is claimed that a continuous monitoring system will warn of any danger to marine life resulting from higher brine concentrations. The effluent has a salt content of about 7 times greater than that of sea water and would therefore tend to sink when discharged.

Uses and specifications

Potash salts are used chiefly in the manufacture of fertilisers either for direct application to the soil or as a component in compound fertilisers, potassium constituting one of the major nutrients essential to plant growth. The Fertilisers and Feedingstuffs Regulations 1973 prescribed under the Agriculture Act 1970, require the percentages of potash (K_2O) nitrogen (N) and phosphate (P_2O_5) in fertilisers to be given as such. These figures indicate the 'grade' of the fertiliser in terms of the concentration of each nutrient, and also provide for the calculation of the so-called plant food ratios. About 96 per cent of United Kingdom (and World) potash consumption is for fertiliser use; the remainder is used for a variety of industrial purposes, notably in the manufacture of chemicals and glass.

Potassium chloride (KCl) is by far the most important potassium salt used, accounting for more than 90 per cent of the potassic fertilisers used in agriculture. The expanding demand for high-analysis products in the fertiliser industry has led to the development of economic techniques for the preparation of high-grade potassium chloride (muriate of potash) containing at least 60 per cent equivalent K_2O and a maximum of 3 per cent common salt. Chemical grade potassium chloride normally contains a minimum of 62 per cent equivalent K_2O; it is used mostly in the manufacture of caustic potash (KOH) and potassium metal. A recent new and increasing use for potassium chloride is in boreholes drilled for oil and gas in the North Sea. Potassium chloride, in concentrations as high as 15 to 20 per cent, is added to polymer mud systems to reduce the incidence of shale hydration and prevent its dispersion into the fluid.

A great deal of attention has also been paid in recent years to the physical nature of the potassium salts marketed. These are normally produced in either soluble, standard, coarse or granular form, depending on the particle size. Standard, coarse and granular material are usually sold on a minimum 60 per cent equivalent K_2O basis, although a minimum 62 per cent K_2O standard grade is sometimes also produced. The soluble product is marketed on a 60 per cent or 62 per cent equivalent K_2O basis. Whereas coarsely crystalline products were formerly acceptable as an alternative to the standard size, some consumers demand a fourth, larger particle size and to this end compaction techniques have been introduced extensively. As a guide, the chemical and physical analyses of the main products marketed by the International Minerals and Chemical Corporation (Canada) Limited, are given below (Table 2). These are produced from potash ore containing 25 to 35 per cent equivalent K_2O, roughly comparable in grade with the deposits being worked in Cleveland.

Table 2 Chemical and physical analyses of Canadian potassium chloride products

Chemical analysis

	Standard	Coarse	Granular
		Per cent	
K	50.54	51.06	50.42
(K_2O equivalent	60.9	61.5	60.80)
Mg	0.11	0.09	0.10
Ca	0.05	0.05	0.05
Na	1.00	0.63	0.86
Cl	47.26	47.24	47.02
SO_4	0.56	0.42	0.51
Br	0.065	0.065	0.065
Insoluble matter	0.28	0.24	0.73
H_2O	0.10	0.10	0.10

Typical sieve specification (cumulative)

	Standard	Coarse	Granular
Tyler mesh + 6	–	–	0.5
8	–	2	18
10	–	15	65
14	2	40	96
20	7	83	98
28	39	97	–
35	68	–	–
48	85	–	–
65	93	–	–
100	97	–	–
200	–	–	–

Source: World Survey of Potash Resources, 1975, p.25.

Potassium sulphate, normally marketed on a 50 to 51 per cent equivalent K_2O basis and generally produced by conversion from potassium chloride, is the second most important potassium salt used in agriculture. It is used in preference to potassium chloride on specialised crops, although in general all potassic fertilisers are equally effective as a source of potassium. Potassium sulphate is used also as an accelerator in the manufacture of gypsum products.

Manufactured potassium salts, again derived mainly from potassium chloride, have a wide variety of commercial applications mainly in the chemical, explosive and glass industries. Caustic potash (KOH) is consumed chiefly in the preparation of potassium phosphates used in liquid detergent manufacture, the processing of rubber, and in high pressure boiler water treatment. Another important application of caustic potash is in the manufacture of potassium carbonate, which is used mainly in the preparation of decorative glass, colour television tubes, fluorescent lamps, chinaware, textile dyes and pigments, Potassium carbonate is the principal source of potassium in the manufacture of high-quality table and decorative glassware and of certain types of optical lenses. Potassium nitrate (saltpetre, KNO_3) is a powerful oxidising agent and is used chiefly in the production of gunpowder and certain plastics. Although long recognised as an excellent fertiliser, its use for this purpose was restricted until comparatively recently because of high production costs. Potassium permanganate is used chiefly in the manufacture of saccharin and as an oxidising, decolourising, bleaching and purification agent. It is also employed, for example, in zinc refining and in the removal of heat scale from stainless steel and refractory metals. Potassium peroxide is used in breathing apparatus and minor amounts of potassium chlorate are employed in the manufacture of matches and explosives.

In recent years a significant increase in the use of potassium salts in the United Kingdom has been accompanied by only minor changes in the relative proportions of potassium salts used by the fertiliser and chemical industries. Such products as potassium metaphosphate and synthetic potassium nitrate may eventually account for a larger percentage than previously of the total tonnage of potassium salts consumed in agriculture and the chemical industry. As most potassium chloride is sold in compound fertilisers, its use is directly related to the agricultural season and to the uptake of nitrogen.

Prior to the introduction of natural potash salts as fertilisers, the principal source of potassium on farms in the United Kingdom was farmyard manure. Wood ashes and small quantities of potassium salts made from kelp were used in certain districts, while during the early 19th century greensand was used in parts of southern England as a fertiliser. It was not until potatoes, sugar beet, fruit, vegetables and other special crops commenced to be grown extensively in the early 20th century in areas with little livestock, that potassic fertilisers began to be used.

Price and cost

Prices for natural potassium salts are usually the subject of negotiation between producer (or marketing agency) and buyer on the basis of differences in grade, freight equalisation credits and various discounts for specific sales contracts. Published quotations should therefore be regarded only as rough guides to prices. Consignments vary from complete shiploads to 6 or 1 ton lots and some potassium chloride and potassium sulphate is supplied bagged. When delivered in bulk, prices are normally quoted in terms of per cent unit of equivalent K_2O, which allows for variations in analysis between shipments. As with most industrial minerals, transportation costs are an important component of both the fob and final delivery price of potassium salts. Prices of potassium salts quoted for delivery within the United Kingdom early in 1975 are shown in Table 3. There is no import duty on the raw material.

Table 3 United Kingdom delivered prices of potassic fertilisers and industrial chemicals

	£ per long ton	*Equivalent £ per tonne*
Fertiliser materials		
Potassium chloride, 60 per cent K_2O, in bags, ex-port stores	40.85	40.20
Potassium sulphate, 50 per cent K_2O, in bags, ex-port stores	80.75	79.48
Potassium nitrate, crystals, 5 – ton, ex-store	119	117
Chilean nitrate, 15 per cent N,14 per cent K_2O, ex-store	72	70.86
Industrial chemicals		
Potassium chloride, 99 per cent, 1 – ton lots	98*(a)*	96.45
Caustic potash, solid, 1 – ton lots	106.50	104.82
Caustic potash, liquid	44	43.30
Potassium carbonate, calcined, 96/98 per cent, 1 – ton lots, ex-store	92 to 100 *(a)*	90.55 – 98.42
Potassium nitrate, 5 – ton lots, in non-returnable packaging, carriage paid	131	128.93

(a) Approximate

Source: Chemical Age, 1975, No. 2942, pp. 23 and 25.

Imports of potassium minerals and compounds into the United Kingdom in 1974 amounted to about 910,000 tonnes valued at about £32,411,000, indicating an average cif UK value of £35.6 per tonne. For potassium chloride imports alone the corresponding value would be £33 per tonne. Since the Second World War prices for potash in the United Kingdom have been relatively stable.

North American prices of potassium salts reached a maximum of US $37.53 per equivalent ton K_2O (£13.19 per tonne) in 1965 but subsequent world potash over-supply forced prices down to about US $11 per tonne (£4.5 per tonne) in 1969. Pro-rationing regulations were introduced in 1970 by the Saskatchewan Provincial Government, which aimed at obtaining optimum financial returns for the domestic potash industry consistent with efficient operation and led to a steady improvement in the potash market. Prices rose in response to the establishment of an ex-mine 'floor' price that has held relatively firm throughout the international market.

The 'floor' price of Can $33.75 per short ton (£16 per tonne) equivalent K_2O determined North American price levels until 1973 when the market became sufficiently firm for higher prices to be introduced. In September, 1975, for example, the listed price for Canadian potassium chloride corresponded to Can $75 per short ton (£36 per tonne equivalent K_2O). Although Canadian potash has tended to dominate world prices, those of European producers have remained low enough to displace Canadian potash from European markets. For example, sales to western Europe amounted to less then 60,000 tonnes equivalent K_2O in 1974, compared with 300,000 tonnes in 1973.

Technology

Most potash deposits, including those at Boulby in Cleveland, are mined underground by conventional room-and-pillar techniques. Their development generally involves considerable capital expenditure; for example, the mining venture at Boulby was undertaken at a capital cost initially estimated at £25 million and now approaching £47 million. Potash can also be extracted by solution mining and this method was tested in the United Kingdom during the 1960s but not brought into commercial operation. In some countries significant quantities of potassium salts are produced also by the solar evaporation of inland brine lakes. The grade of deposits mined varies considerably, generally amounting to between 12 and 35 per cent equivalent K_2O. Beneficiation by either flotation or solution and recrystallisation is normally required to provide marketable products.

Mining

At Boulby two lined shafts 5.5 m in diameter and 91 m apart have been sunk to depths of about 1,150 m. Special techniques, including freezing, were employed to overcome problems posed by the presence at depths of between 600 and 930 m of the Bunter Sandstone, an aquifer containing brine at pressures of up to 96 kg/cm^2. These shafts are the deepest in the United Kingdom, only marginally less than the 1,200 m depth reached in the course of potash operations in the Federal Republic of Germany in 1974. Mining involves excavating roadways nearly 3.5 m high and some 6 m wide on a rectangular plan with supporting pillars. These are 36 m square, resulting in the recovery of 25 per cent of the ore in place. A potash section 1 to 2.5 m thick and containing up to 19 per cent equivalent K_2O is extracted by drilling and blasting and carried in load-haul-dump machines with 5 yd^3 (3.8 m^3) buckets to feederbreakers which reduce the ore to minus 6 in (152 mm) and discharge the rock on to belt conveyors leading to three 1,000 tonne storage bunkers. Before hoisting the rock is further crushed to minus 4 in (102 mm). The rock shaft is equipped with two 20-tonne skips giving it a hoisting capacity of 4.5 million tonnes a year.

The solution mining of potash was tested by Imperial Chemical Industries Limited from 1952 to 1954 at one of their deep boreholes in North Yorkshire but the results were not considered encouraging and the project was abandoned. Trials were also carried out during the 1960s by Whitby Potash Limited on Egton Low Moor south-west of Whitby, based on a process developed by the Pittsburgh Plate Glass Company, Pennsylvania, and comparable with that employed in the solution mining of rock salt. Brine is introduced through concentric pipes into the deposit to dissolve the orebody and raise the resulting solution to the surface. Water containing potassium and sodium chlorides in a pre-determined concentration is injected into the potash bed at a temperature of about 45°C to dissolve the KCl and $NaCl$ in approximately the same ratio as that present in the parent rock. On return to the surface the nearly saturated solution is discharged into a shallow pond where it is cooled sufficiently to enable the KCl to crystallise, the NaCl remaining in solution. The original saline solution is then re-adjusted and heated before recirculation. While it is claimed that any horizontally bedded sylvinite deposit may be mined in this way, the process is generally limited to raw material containing at least 15 per cent and usually more than 25 per cent KCl. Since 1964 potash has been produced by this method on a commercial scale near Regina, Saskatchewan, from deposits lying at a depth of about 1,500 m.

Brines, such as those of the Dead Sea which contain about 1.0 per cent KCl at the surface, are pumped into a conductor canal and led to a series of evaporation pans, the concentrating brine becoming saturated with sodium chloride which crystallises out and is removed by washing. When Dead Sea brine reaches a specific gravity of 1.3, it is transferred to a second set of pans for the crystallisation of carnallite, this mineral being then harvested by dredger and pumped as a slurry to the nearby plant for processing. Evaporation is accelerated by the addition of a colour compound.

Beneficiation

Flotation or solution and recrystallisation are the standard methods used to produce marketable grades of potassium salts. Both techniques have certain advantages, the method employed generally depending on the character of the potash mined and the quality of the product required for existing markets. Flotation is a less expensive process for lower grade ores than solution-recrystallisation, but the latter method, favoured for many years in Europe particularly for the extraction of carnallite and kainite, generally yields a rather better product in terms of particle size and K_2O content. For this reason, many flotation plants also have auxiliary solution - recrystallisation units.

At Boulby the potash ore is reduced to -20 mesh (0.85 mm) in impact crushers and rod mills and, after the addition of brine, is wet screened and cycloned to eliminate slimes prior to treatment in flotation cells (Fig 4). In the main flotation circuit, sylvine is separated from common salt (halite) by using an amine together with mineral oil; starch is employed as a depressant. A 60 per cent K_2O concentrate is produced, which is then dewatered, dried and screened to yield a product of 0.85 mm particle size. By a leach and crystallisation procedure, a high grade concentrate with 62 per cent K_2O is also produced from the slimes flotation concentrate. The compaction circuit treats the fines obtained by screening the dried flotation concentrate, the compacted material being itself screened to provide coarse and granular grades. At most flotation plants potash recovery generally exceeds 90 per cent.

The solution and recrystallisation of potassium chloride from solid potash ores is a much older and well-established process. The solubility of most salts increases with rising temperature, but sodium chloride is unusual in that it is only slightly more soluble in hot than in cold water. This difference in relative solubility is used to extract the potassium chloride from sylvinite, the ore being leached with hot brine which dissolves more potassium salt than sodium salt. The saturated brine is then clarified and cooled, so that potassium chloride crystallises freely leaving sodium chloride in solution. The crystals are recovered and the brine re-circulated. Processing carnallite is more complex because of the variety of other minerals that are generally present; both hot leach and cold leach stages may be incorporated into the flowsheet. In the Federal Republic of Germany sylvinitic ore containing 25 per cent carnallite and some kieserite is processed.

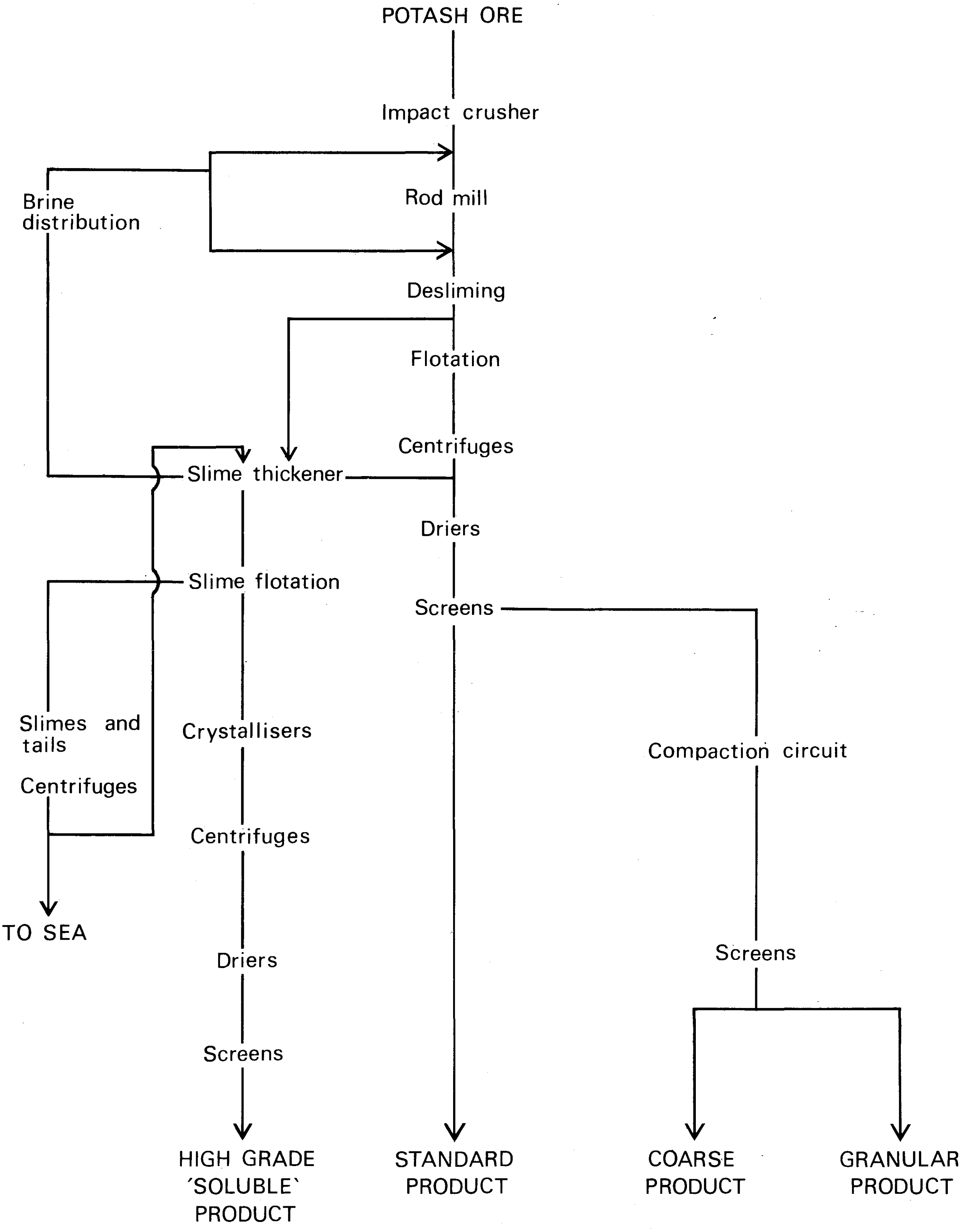

Fig 4 Simplified flow diagram, Boulby potash refinery, Cleveland

Production

Small quantities of sylvinite have been raised from one shaft at the Boulby mine since October 1973, and the second shaft specifically intended for ore haulage was fully commissioned in September 1975. By the end of 1975, almost 60,000 tonnes of marketable potassium chloride had been produced. The mine has an initial capacity of 1 million tonnes of potassium chloride a year but this can be readily uprated to 1.5 million tonnes. It is therefore nominally capable of supplying the entire United Kingdom market for potash, although it seems unlikely that imports will cease entirely. World production of potash is dominated by the USSR, Canada, the Federal Republic of Germany, the USA, the German Democratic Republic and France. These countries accounted for about 92 per cent of the total world output of 24 million tonnes K_2O in 1974 (Table 4).

Commercial extraction of potassium chloride began in 1861 at Stassfurt, in what is now the German Democratic Republic, Germany enjoying a virtual world monopoly of production up to the First World War. With the discovery of potash deposits in Alsace in 1904, Germany was joined by France as a major producer, and in the USA saline potash minerals were produced from Searles Lake on a significant scale during the First World War, when supplies from Germany were cut off. In 1931 the first underground potash mines in the USA began production near Carlsbad, New Mexico, and in the USSR in the northern Urals near Solikamsk. Among the most important developments in the world potash industry since the Second World War has been the opening up of deep deposits in Saskatchewan, western Canada, during the 1960s and the relatively rapid growth of the USSR potash industry.

Table 4 World production of potassium minerals, 1970-1974, by major producing countries

Country	*Thousand tonnes K_2O*				
	1970	1971	1972	1973	1974
Soviet Union	4,087	4,807	5,433	5,917	6,500
Canada	3,173	3,573	3,928	4,249	5,496
Federal Republic of Germany	2,306	2,443	2,449	2,548	2,621
German Democratic Republic	2,419	2,445	2,458	2,556	2,865
USA	2,476	2,347	2,412	2,361	2,309
France	1,768	1,870	1,624	2,263	2,073
Spain	520	508	533	473	396
Israel	546	568	578	531	607
Others (*a*)	506	707	748	799	854
Total	17,801	19,268	20,163	21,697	23,721

(a) Including Italy, Congo Republic, Chile, China and the United Kingdom

Source: Institute of Geological Sciences.
The British Sulphur Corporation Limited.

Overseas trade and consumption

The United Kingdom has for many years been a major importer of potassium salts, of which the most important is potassium chloride (muriate of potash). Imports of potassic fertilisers have more than doubled over the last 25 years, from about 420,000 tonnes in 1950 to about 890,000 tonnes in 1974 (Table 5). There was, however, a decrease in imports in 1972 which reflected the Government decision to reduce fertiliser subsidy payments at the end of the 1971-72 fertiliser year. Although potash for direct application was not subsidised, potassium-containing compound fertilisers were, and a relatively large tonnage of these compound fertilisers was purchased in advance in order to qualify for subsidy payments.

About 910,000 tonnes of potassium minerals, manufactured fertilisers and industrial compounds were imported into the United Kingdom in 1974 valued at over £32 million cif, of which potassium chloride accounted for 805,498 tonnes valued at nearly £27 million cif (Table 6, Fig 5). The average cif value per tonne of all imports in 1974 was approximately £35.60, and that of potassium chloride about £33.00.

Table 5 United Kingdom: Imports of potassic fertilisers, 1950-1974

Year	*Crude natural potassium salts*	*Potassium chloride (a)*	*Potassium sulphate (b)*	*Potassium nitrate (c)*	*Other potassic fertilisers (d)*
1950	1	403	14	0	–
1951	9	452	14	1	–
1952	26	344	12	0	–
1953	31	513	10	1	–
1954	39	481	7	1	–
1955	36	518	14	1	–
1956	38	562	13	2	–
1957	38	546	16	1	–
1958	39	591	16	3	–
1959	45	621	25	3	–
1960	43	723	23	3	–
1961	56	705	22	3	–
1962	53	678	25	3	–
1963	29	691	28	3	16
1964	38	673	34	3	7
1965	38	691	34	3	3
1966	36	641	38	4	7
1967	43	728	37	4	3
1968	37	763	41	–	4
1969	37	701	41	–	3
1970	24	760	35	10	28
1971	35	811	38	9	27
1972	38	663	26	8	40
1973	35	731	43	11	30
1974(*p*)	26	805	32	11	17

(*p*) Provisional
(*a*) Estimated K_2O content 60 per cent
(*b*) Estimated K_2O content 50 per cent
(*c*) From 1963 classified as an inorganic chemical whether or not used as a fertiliser
(*d*) Manufactured potassic fertiliser materials including prepared mixtures of two or more potassium fertilising salts or of natural potassium and sodium nitrates

Source: HM Customs and Excise; Institute of Geological Sciences.

Table 6 United Kingdom: Imports of potassium minerals and compounds, 1970-1974

	Unit	*1970*	*1971*	*1972*	*1973*	*1974(p)*
Crude natural salts	*tonnes*	24,321	35,388	37,803	35,217	26,199
	£ cif	207,086	347,839	377,741	420,247	407,000
Manufactured fertiliser materials						
Chloride	*tonnes*	759,510	811,024	663,001	731,062	805,498
	£ cif	11,175,597	13,148,472	11,633,145	16,021,200	26,721,000
Sulphate	*tonnes*	34,529	38,115	25,589	43,236	32,246
	£ cif	715,365	808,812	581,185	1,147,836	1,312,000
Nitrate	*tonnes*	9,919	9,163	8,481	10.896	11,375
	£ cif	534,930	514,181	484,884	743,883	1,047,000
Others	*tonnes*	20,375	20,977	34,867	26,922	8,745
	£ cif	232,728	296,415	611,386	623,387	223,000
Prepared mixtures (a)	*tonnes*	7,377	5,207	5,425	3,371	7,971
	£ cif	188,092	134,932	145,798	103,801	413,000
Carbonate	*tonnes*	11,185	10,884	10,886	14,381	13,301
	£ cif	719,025	777,280	822,179	1,163,593	1,543,000
Sulphate	*tonnes*	113	130	140	146	179
	£ cif	7,151	7,519	9,326	13,277	18,000
Hydroxide and peroxide	*tonnes*	2,658	2,602	2,588	3,222	3,859
	£ cif	235,859	244,626	258,476	359,173	563,000
Chlorate and perchlorate	*tonnes*	995	1,003	863	755*(b)*	912*(b)*
	£ cif	106,060	110,033	106,312	102,803	164,000
Total value	*£ cif*	14,121,893	16,390,109	15,030,432	20,699,200	29,411,000

(*p*) Provisional

(*a*) Two or more potassium fertilising salts or of natural potassium and sodium nitrates

(*b*) Chlorate only

Source: HM Customs and Excise.

Five countries accounted for about 80 per cent of United Kingdom imports in 1974: the German Democratic Republic (34 per cent), the Federal Republic of Germany (20 per cent), the Soviet Union (12 per cent), France (6 per cent), and Israel (8 per cent). In addition the considerable quantity of fertilisers imported from Belgium-Luxembourg probably originated from the Federal Republic of Germany, France and the Soviet Union (Table 7). Imports of potassium chloride from Canada have declined markedly, from 221,000 tonnes in 1967 to 16,700 tonnes in 1974.

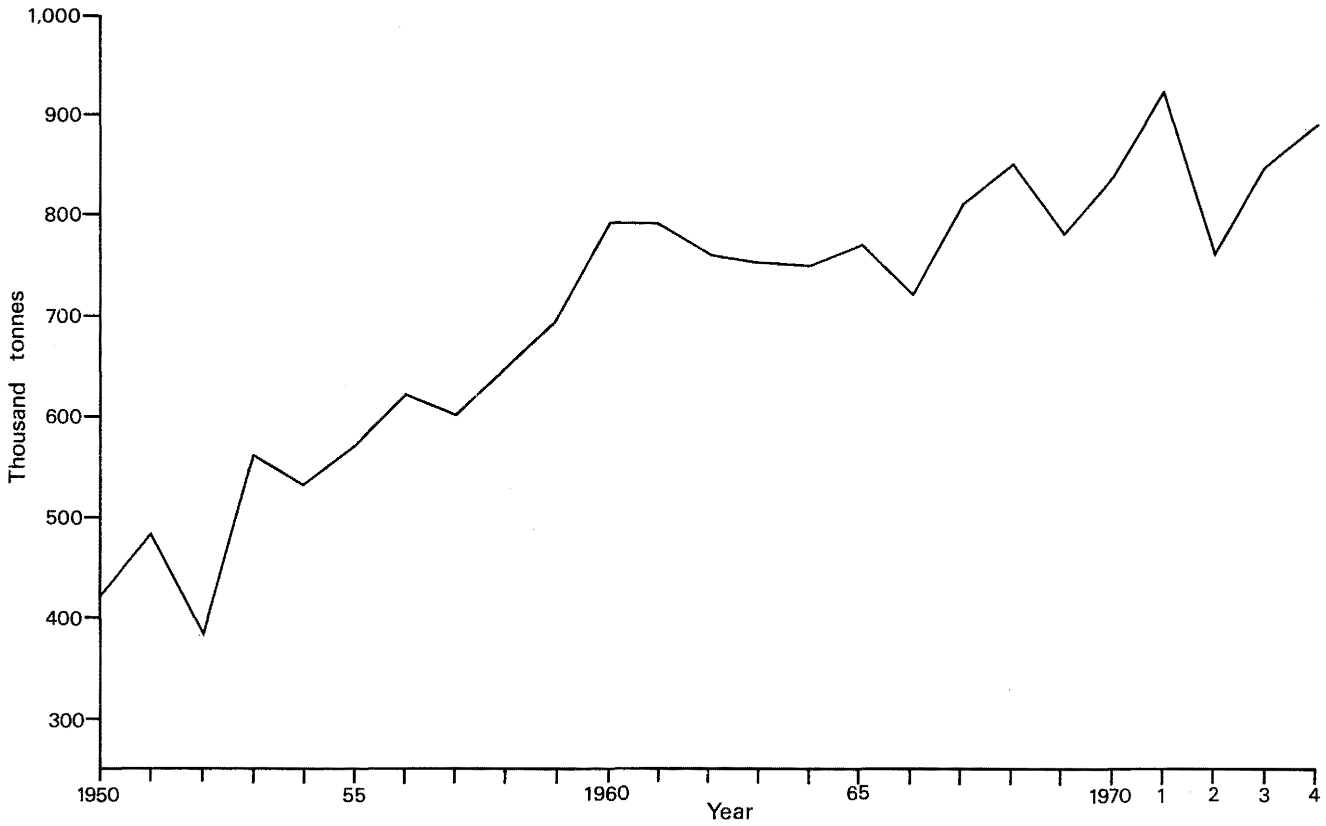

Fig 5 United Kingdom: Imports of potassium salts for fertiliser use, 1950-1974

Exports (including re-exports not separately shown in the United Kingdom Trade Accounts since 1970) are relatively small, amounting to some £2.3 million fob in 1974, the main export items being the fertiliser potassium chloride, potassium iodide and potassium cyanide (Table 8). Exports of potassium chloride have risen sharply since 1972. In addition export earnings arise from the considerable volume of potassium exported in the form of compound fertilisers, the value of which in 1974 was about £1 million. The current dependence on imports produces a marked deficit in the balance of payments amounting in 1974 to about £30 million. A considerable saving in foreign currency is expected once the Boulby mine is fully operational.

From 1970 both imports and exports of potassium minerals, manufactured fertilisers and industrial compounds have been recorded by headings of the United Kingdom Tariff and the Overseas Trade Classification; the major headings and code numbers for 1974 were as follows:

Potassic mineral or chemical (manufactured) fertilisers

3104 0637	Potassium salts, crude, natural
3104 0758	Potassium chloride
3104 0893	Potassium sulphate
3104 1034	Other
3104 1155	Fertilisers as above, mixed together

Table 7 United Kingdom: Imports of potassic fertilisers, by countries, 1970-1974

	1970	*1971*	*1972*	*1973*	*Tonnes 1974(p)*	*£ per tonne Average cif value in 1974*
Crude natural potassic salts						
From:						
German Democratic Republic	20,477	24,572	24,007	21,418	21,666	15
Germany, Federal Republic	2,119	7,353	8,950	12,300	2,716	16
Israel	1,074	3,463	4,846	1,499	1,600	16
Other countries	681	–	–	–	217	23
Total	224,321	35,388	37,803	35,217	26,199	16
Potassium chloride						
From:						
German Democratic Republic	257,766	275,409	226,141	214,297	262,039	33
Germany, Federal Republic	88,324	116,700	73,360	145,211	167,951	33
Soviet Union	83,322	81,028	102,923	130,211	103,873	33
France	91,827	101,339	75,788	75,321	48,543	35
Israel	58,952	47,981	50,974	50,071	73,906	34
Belgium-Luxembourg	12,164	12,408	46,515	47,595	59,567	31
USA	47,053	20,575	11,300	1,870	33,189	30
Canada	31,961	12,041	29,470	39,870	16,742	38
Spain	83,389	70,563	43,223	9,850	5,341	36
Congo (Brazzaville)	1,708	9,943	–	10,820	22,810	34
Netherlands	2,811	62,421	2,327	2,381	3,605	37
Other countries	232	616	980	3,565	7,932	36
Total	759,510	811,024	663,001	731,062	805,498	33
Potassium sulphate						
From:						
German Democratic Republic	8,632	11,265	6,510	5,028	7,497	42
Germany, Federal Republic	11,355	16,953	9,246	12,112	11,221	45
France	12,689	8,225	9,833	20,060	9,166	40
Belgium-Luxembourg	23	552	–	4,781	2,506	35
Canada	457	–	–	1,230	–	–
Netherlands	–	19	–	18	54	93
Irish Republic	1,371	–	–	7	–	–
Spain	–	1,101	–	–	–	–
Other countries	2	–	–	–	1,802(*a*)	22
Total	34,529	38,115	25,589	43,236	32,246	41
Potassium nitrate						
From:						
Germany, Federal Republic	4,799	5,424	4,925	5,840	6,258	90
France	377	390	465	467	194	99
Israel	2,381	2,352	2,129	3,438	4,006	84
Poland	1,541	755	722	1,100	1,060	101
Spain	415	112	195	50	–	–
Netherlands	250	–	20	–	20	87
Other countries	157	130	25	1	128	124
Total	9,919	9,163	8,481	10,896	11,666	90

Table 7 (contd.)

	1970	*1971*	*1972*	*1973*	*Tonnes* *1974(p)*	*£ per tonne Average cif value in 1974*
Other manufactured potassic fertiliser materials						
From:						
German Democratic Republic	5,399	2,253	19,934	20,474	6,424	25
Germany, Federal Republic	7,212	5,668	1,580	–	193	26
Soviet Union	–	1,827	–	–	–	–
France	2,050	767	–	30	0	–
Israel	2,877	9,955	13,353	6,284	425	24
Spain	2,821	–	–	–	–	–
Other countries	16	507	–	134	1,703	26
Total	20,375	20,977	34,867	26,922	8,745	26
Prepared mixtures (b)						
From:						
Chile	5,462	5,200	5,375	3,334	1,867	52
Other countries	1,915	7	50	37	6,104	52
Total	7,377	5,207	5,425	3,371	7,971	52

(p) Provisional except for potassium nitrate

(a) USA only
(b) Fertilisers consisting solely of two or more potassic fertilising salts or of natural potassium and sodium nitrates

Source: HM Customs and Excise.

In addition some mixed and compound potassic fertilisers appear under code 3105, which includes all mixed fertilisers containing two or more plant nutrients. The headings for earlier years were the same, although the second four digits of the code numbers were changed in 1974 (as shown) and a new heading 3104 1155 was added. Potassium nitrate was classified as a fertiliser in the Fertiliser Section until 1962, but from 1963 was classified as a chemical compound in chapter 28 of the Tariff (2839) in which chapter other chemically defined potassium compounds are included.

Demand trends

The need for potassium salts tends to vary with the level and pattern of agricultural activity and to increase as agricultural productivity intensifies. In the United Kingdom the demand for fertilisers has increased substantially since the Second World War and this has been directly reflected in the demand for potash. For example, there was a decline in demand for potash in 1973, corresponding to a general, though only temporary, reduction in fertiliser usage. Consumption has grown at an average rate of 3.1 per cent a year during the period 1965-1974 and in 1974 amounted to 484,000 tonnes equivalent K_2O (Table 9). If this trend is maintained, UK consumption by 1980 will be approximately 581,000 tonnes equivalent K_2O. For western Europe as a whole, which accounts for more than one-quarter of total world consumption of potash, an average annual growth rate of 3 per cent to 1980 has been predicted.

Table 8 United Kingdom: Exports of potassium minerals and compounds, 1970-1974(*a*)

	Unit	*1970*	*1971*	*1972*	*1973*	*1974(p)*
Crude natural potassium salts	*tonnes*	1,232	27	139	90	24
	£ fob	11,493	1,133	4,216	1,924	2,000
Manufactured potassic fertiliser materials						
Chloride	*tonnes*	448	428	738	1,149	8,557
	£ fob	13,540	35,546	44,416	80,003	971,000
Sulphate	*tonnes*	3,984	302	162	2	136
	£ fob	130,549	1,291	5,190	72	8,000
Nitrate	*tonnes*	80	27	27	51	59
	£ fob	13,834	13,651	9,714	16,889	17,000
Others	*tonnes*	6,587	758	1,922	681	1,133
	£ fob	26,437	14,422	28,337	22,884	85,000
Prepared mixtures (*b*)	*tonnes*	4,697	4,457	1,296	555	3,357
	£ fob	132,886	82,520	82,031	41,015	185,000
Carbonate	*tonnes*	154	88	26	175	156
	£ fob	8,620	6,868	3,430	16,502	33,000
Sulphate	*tonnes*	320	187	157	352	210
	£ fob	31,992	18,871	10,358	21,016	67,000
Hydroxide and peroxide	*tonnes*	617	612	800	871	1,221
	£ fob	82,160	105,916	77,922	99,852	199,000
Chlorate and perchlorate	*tonnes*	44	7	6	18	24
	£ fob	4,238	1,588	2,346	2,975	11,000
Iodide	*tonnes*	219	184	151	218	167
	£ fob	272,356	325,618	256,852	382,895	394,000
Manganate (*c*)	*tonnes*	381	232	40	101	187
	£ fob	86,569	57,930	11,471	21,752	74,000
Cyanide	*tonnes*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*
	£ fob	*n.a.*	*n.a.*	*n.a.*	*n.a.*	270,000
Total value	*£ fob*	814,674	665,354	536,283	707,779	2,316,000

(*p*) Provisional

n.a. Information not available

(*a*) Including re-exports
(*b*) Two or more potassium fertilising salts or of natural potassium and sodium nitrates
(*c*) Figures for years 1970-1973 include potassium perrhenate

Source: HM Customs and Excise.

World potash production capacity, which was estimated to be around 24 million tonnes K_2O in 1974, has been more than adequate to meet world demand, particularly since the development in the 1960s of the Canadian potash industry, which will probably continue to be a major factor in world markets for some years.

A review of the historical growth in the per capita use of potassium has led the US Bureau of Mines to estimate a demand in the USA of between 8.5 million and 15.5 million short tons (7.7 and 14 million tonnes) by the year 2,000, indicating average growth rates of 2.77 and 4.71 per cent respectively from 1968. For the rest of the world, demand was estimated at between 40 and 60 million short tons (36 and 54 million tonnes), implying growth rates of 4.21 and 5.54 per cent respectively. Another estimate (made in 1972) is that world consumption will increase from 19 million tonnes in 1971-72 to about 31 million tonnes equivalent K_2O in 1979-80, based on a 6 per cent growth rate.

Table 9 United Kingdom: Consumption of potassic fertilisers, 1950-1974 (*a*)

	Thousand tonnes K_2O	
	Fertiliser year (*b*)	Calendar year
1950	261	225
1951	275	222
1952	221	185
1953	251	258
1954	277	246
1955	278	279
1956	333	332
1957	343	345
1958	354	359
1959	381	413
1960	433	442
1961	439	438
1962	422	411
1963	417	428
1964	427	414
1965	416	427
1966	418	401
1967	431	455
1968	459	473
1969	444	443
1970	443	472
1971	493	494
1972	450	404
1973	437	454
1974	472	484

(*a*) Home deliveries
(*b*) Years ended 30 June prior to 1965 and 31 May subsequently

Source: Central Statistics Office.

Substitutes

Deposits of soluble potassium minerals are relatively abundant and the marketed products derived from them are comparatively cheap. It is therefore unlikely that any other source of potassium could substitute economically. Some sodium compounds could conceivably be used in place of potassium compounds in certain chemical applications, but for agriculture no such substitution is possible, potassic fertilisers being essential for healthy plant growth and in regulating the intake of other plant nutrients. During the early part of the 19th century deposits of greensand were worked in parts of southern England and used as a fertiliser. One of the largest pits, in the Upper Greensand at Worldham in Hampshire, is believed to have produced thousands of tonnes of marly greensand, the fertilising value of which appears to have been recognised in the United Kingdom as early as 1790. A survey of deposits in Surrey carried out during the Second World War by the Geological Survey in collaboration with the Non-Ferrous Minerals Development Control (Ministry of Supply) led to an investigation by the Building Research Station shortly after the war into the feasibility of extracting potash from Knaphill glauconite sand. Laboratory tests indicated that the most promising method is to burn greensand with calcium or sodium chloride and chalk. Some 40 tonnes of burnt product would need to be required to produce one tonne of potash and it was concluded that production costs would be very high unless some use could be found for the large amount of waste. It was also suggested that colliery wastes, such as those in South Wales which contain 3 to 4 per cent K_2O, offered better prospects in the simultaneous extraction of both potash and alumina.

The recovery of potash from feldspar was considered during the First World War and a number of granitic pegmatites were investigated in North-West Scotland, notably in Sutherland and on South Harris in the Outer Hebrides, but none of the occurrences was worked. Experiments carried out shortly before and during the war, some under Government auspices, showed that orthoclase or microcline could be processed so that about 75 or 80 per cent of the potash present became available in the soluble form. Considerable attention was also given to the possibility of recovering potash from blast furnace flue dust, as the result of an examination of dust from a plant operated at the Scunthorpe works of the North Lincolnshire Iron Company Limited. For this purpose the British Potash Company was formed and a factory was erected at Oldbury near Birmingham without, apparently, coming into commercial production. It was considered at the time that the smallest economic unit was one which had an output of not less than 25,000 tonnes of potassium chloride a year. During the First World War blast furnace flue dust was introduced on the market in the USA as a source of potassium. In the United Kingdom an attempt was made in 1919 to recover potash from cement-kiln dust.

The preparation of potassium salt from the ashes of seaweeds, known as kelp in Europe, has been carried on in Scotland since at least 1730, with output at the beginning of the 19th century reaching about 20,000 tonnes a year. Competition from the bedded potash deposits of Europe and iodine from Chilean nitrate greatly reduced the importance of the Scottish kelp industry and large-scale commercial production ceased in the late 1930s. Small quantities of seaweed continue to be collected and sold as fertiliser, notably on the south-west coast of Scotland, Devon, Cornwall and the Scilly Isles.

A process for recovering potash from the Fucoid Beds in the North-West Highlands of Scotland investigated by the Warren Spring Laboratory from 1963 to 1965 is based on the fusion of potassium-rich shale with limestone (mixed in the ratio of 3:1 respectively) at 1,500°C. Potassium in the form of potassium nitrate can be extracted by dissolution in water, while the insoluble residue was considered suitable for cement making. It was estimated that a plant handling about 200 tonnes of shale a day, the suggested minimum commercial capacity, could produce about 600 tonnes of cement and 40 tonnes of potassium nitrate a day. The feasibility of using magnesia-free limestone from the Fort William area was considered.

Industry

The company operating the Boulby mine, Cleveland Potash Limited, was registered in the United Kingdom in 1967 and is jointly owned by Charter Consolidated Limited and Imperial Chemical Industries Limited (ICI). Charter Consolidated, a subsidiary of the Anglo American Corporation of South Africa Limited, has also a financial interest in the Canadian potash industry.

At Boulby there is covered storage capacity for 40,000 tonnes of product, but it is proposed that the output from the potash refinery will normally be loaded into bottom-dump railcars of 60-tonne capacity and transported directly to a terminal at Tees Dock, Grangetown, 3 km from the mouth of the River Tees. Six unit trains, each carrying 500 tonnes of potash will run each day between the mine and Tees Dock, a distance of 24 km. The railway route incorporates existing track between Carlin How and Teesside but a 7 km dismantled section of the railway line which formerly passed the mine site and extended to Whitby has been reinstated as a private siding owned by Cleveland Potash. At Tees Dock a storage shed of 56,000 tonne capacity has been constructed by the Tees and Hartlepool Port Authority, together with two ship-loaders each capable of handling 1,000 tonnes an hour. Bulk carriers up to the 30,000 tonnes dwt limit imposed by the river draft can be accommodated. The terminal, which is operated by Tees Bulk Handling, a subsidiary of Cleveland Potash Limited, is claimed to be the most modern of its kind in Europe, and will handle phosphate rock as well as potash for delivery to ICI's Billingham fertiliser plant situated some 8 km up-river from the terminal.

During the late 1960s there were two other prospective potash producers in the United Kingdom which, together with Cleveland Potash Limited, could conceivably have raised production of marketable potash to around 3 million tonnes a year. In 1966 Whitby Potash Limited, then a wholly-owned subsidiary of Armour and Company, Chicago, USA, and now owned by Shell Petroleum Company, erected a pilot plant for the extraction of potash by solution mining on Egton Low Moor. The project, which was to have been financed by Armour and Company and Starhaven Refineries Limited, a wholly-owned subsidiary of the Shell Petroleum Company Limited, was shelved in 1971 after an expenditure of about £1 million. Output would have amounted to some 450,000 tonnes of potassium salts a year. Armour and Shell had previously been associated with the manufacture and sale of agricultural chemicals in the United Kingdom by Shellstar Limited and a plant was constructed at Ince Marshes in Cheshire which, it was estimated, would consume nearly 100,000 tonnes a year of the potassium salts produced by Whitby Potash. Armour was formerly a partner with Pittsburgh Plate Glass Company in the solution mining of potash in Canada.

The third project, which was also shelved in 1971, was to have been undertaken by Yorkshire Potash Limited, a wholly-owned subsidiary of the Rio Tinto-Zinc Corporation Limited (RTZ), after more than £1 million had been spent on exploration and preliminary feasibility studies. The mine and

and beneficiation plant with a planned output of about 1 million tonnes of refined potassium chloride were to have been sited at Hawsker Bottoms, nearly 5 km south-east of Whitby. It was proposed to mine potash at a depth of about 1,290 m. RTZ is a major British mining company also linked with the Canadian potash industry.

Both these projects were shelved because of a decline in world potash prices and trade prospects brought about by the development of excess capacity in Canada. However both companies in 1975 applied for extensions to the periods originally covered by their planning permissions.

The major consumers of potassium salts in the United Kingdom are: Fisons Limited, Imperial Chemical Industries Limited and its subsidiaries, and Shellstar Limited, as well as Albright and Wilson Limited, Lindsey and Kesteven Fertilisers Limited and Seabright Chemicals Limited (Table 10). Most of the potash imported into the United Kingdom from western Europe and the USSR has been sold for many years by Potash Limited, a company formed in 1939. However, following an EEC decision in 1974 that the French and Federal German potash industries should discontinue their joint marketing arrangements, a new company, Potash & Continental Limited, was set up to market French potash in the United Kingdom. Sales of potash from the German Democratic Republic are handled by Propane Fertilisers Limited, a company set up in 1954 which accounts for almost one-third of total potash sales in the United Kingdom.

Table 10 Ownership and location of major plants manufacturing fertilisers which incorporate potash in the United Kingdom

Name of Company	*Plant*
Albright & Wilson Ltd (*a*)	Barton-on-Humber Bourne
J W Chafer Ltd (*b*)	Chedburgh (*c*) Micheldever (*c*)
Fisons Ltd	Avonmouth Barking Boston Goole Immingham Ipswich Plymouth Widnes
Hargreaves Fertilisers Ltd (*b*)	Beverley Blunham Bridlington Howden Elvington (*c*) Perth (*c*) Wisbech (*c*)
Imperial Chemical Industries Ltd	Billingham Severnside
Lindsey & Kesteven Fertilisers Ltd	Saxilby
Richardsons Fertilisers Ltd (*b*)	Belfast Lisahally
Scottish Agricultural Industries Ltd (*b*)	Sandilands (Aberdeen) Leith
Seabright Chemicals Ltd	Barking
Shellstar Ltd (*d*)	Ince Marshes

(*a*) Marchon Division
(*b*) Subsidiaries of Imperial Chemical Industries Ltd
(*c*) Liquids only
(*d*) Subsidiary of the Dutch fertiliser group Unic van Kunstmestfabrieken by

Source: The Fertiliser Manufacturers Association Limited.

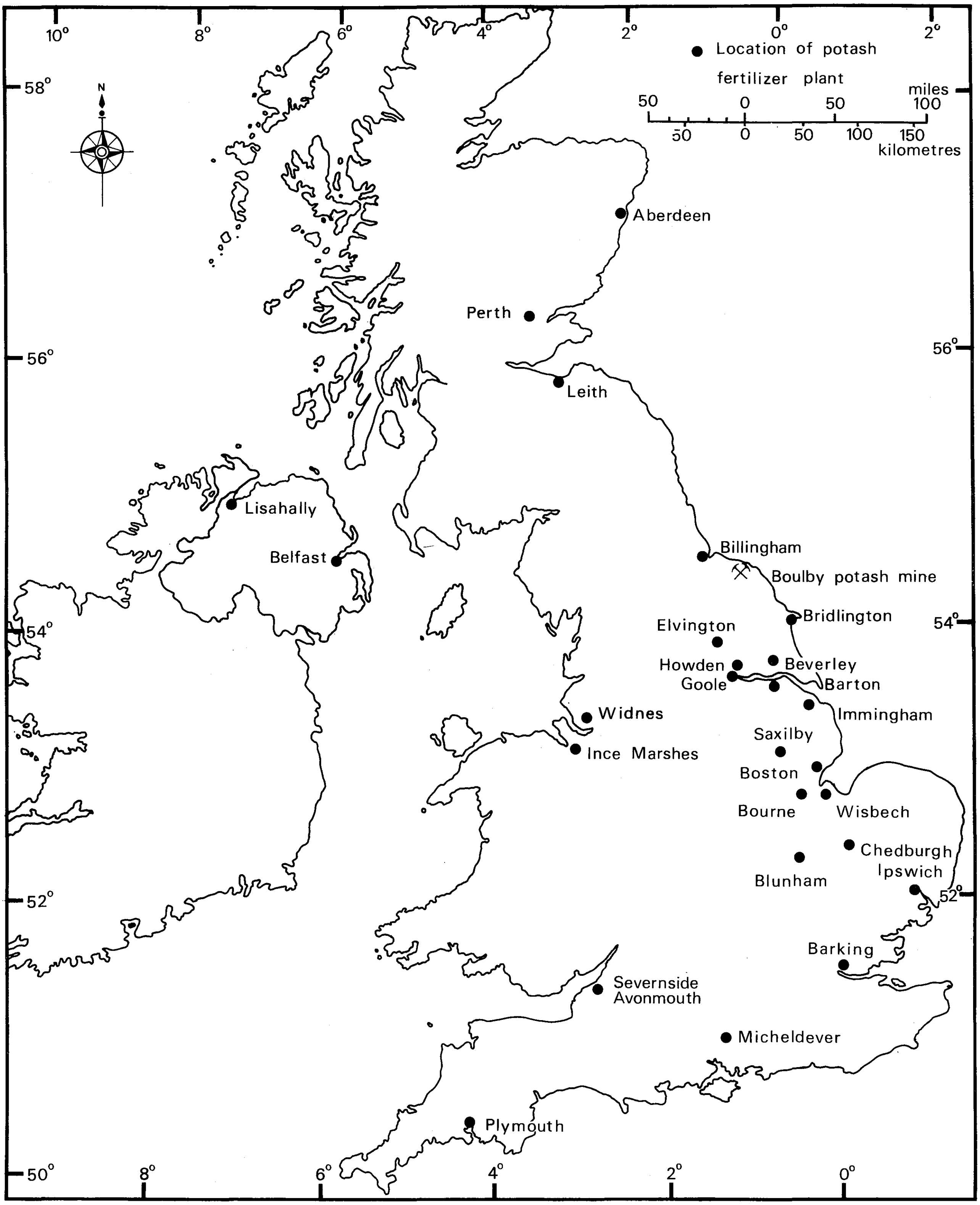

Fig 6 Location of major potash fertiliser plants in the United Kingdom

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