Mineral Resources
Consultative Committee

Mineral Dossier No 14

Gold

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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

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Metric units are used 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
kilogrammes	(kg)	= troy ounces x 0.0311035
tonnes	(1,000 kg)	= long tons x 1.016047
tonnes		= short tons x 1.102311
gramme		= pennyweights x 0.643014
grammes per tonne		= pennyweights/short ton x 0.5833
	=	= pennyweights/long ton x 0.653333

Contents

Illustrations

Summary

Gold is a soft heavy yellow metal used since prehistoric times for jewellery. It has for centuries been used in coinage: gold sovereigns are still valid as currency but, as they are worth many times their face value, they are now minted mainly for collectors. Gold is being used for an increasing range of industrial applications, particularly in miniaturised components in the electronics industry. The recent price increases appear to have influenced use in electronics; thinner coatings and smaller gold areas now being employed. The industrial use of gold is relatively small in the United Kingdom compared with the USA, Japan and West Germany, being about 30 tonnes in 1973.

Gold was mined in the United Kingdom, mainly in Wales, for centuries, and about 4 tonnes of gold has been recovered since 1860. However, none has been produced for over 30 years. Most of the gold-bearing deposits found in Great Britain are alluvial and occur adjacent to the 4°W line of longitude. The main world producer of gold is South Africa, followed by the Soviet Union, and total production of new gold is probably now a little under 1,500 tonnes a year.

The price of gold was fixed by legislation during much of the 20th century. The recent high price of gold has decreased hoarding in developing countries, but considerable quantities of gold bullion are held in most of the developed world. The United Kingdom imported over 554 tonnes of refined bullion in 1974, and nearly 168 tonnes of gold in other forms. The net export of gold increased from nearly £180 million in 1973 to over £1,000 million in 1974.

Terminology

Lode gold is gold which occurs in a vein. A *reef* is a lode of auriferous quartz.

Alluvial or *placer gold* occurs in alluvial gravels and is found in a great variety of forms. It can look black or rusty or appear to be light in weight when the particles of gold are very small. The terms used to describe alluvial gold are listed alphabetically as follows:

Beach gold (as on the west coast of South Island, New Zealand) consists of fine spangles that are floated away by the least movement of water.
Black gold is alluvial gold coated by black manganese oxide.
Branny gold (as in Victoria) consists of thin scales roughly resembling bran.
Cornet gold is very thin plates of gold rolled up to form small cylinders.
Dust gold consists of compact particles of gold the size of ground pepper.
Float gold consists of particles so fine that they easily rise to the surface of water and are difficult to re-immerse.
Flour gold is even finer than float gold.
Hackly gold is particles which have not been water worn and therefore have quite sharp edges and rough surfaces.
Light gold consists of samples which are bulky for their weight.
Melon seed gold consists of extremely well-worn particles with flat, rounded forms and smooth surfaces.
Nuggets are masses of gold weighing over about 30 grammes and up to 50 kg or more.
Rough gold is pieces of gold weighing over 2 grammes.
Rusty gold is particles covered with a thick coating of limonite.
Scaly gold is quite common in swiftly flowing rivers. Some scales are fairly large, others are microscopic in size.
Seed gold consists of small particles of very uniform size and shape.
Shot gold consists of spherical grains resulting from the wearing of gold crystals by water.
Shotty gold is compact, well-rounded and about the size of peas and small beans.
Slime or *Slum* gold is recovered from washing slimes from puddling machines and consists of fine crystals and minute particles.
Slugs is a Western Australian term for nuggets.
Water-worn gold is thoroughly rounded gold subjected to attrition in the bed of a stream.
Wind-worn gold (as found in parts of Western Australia) is particles with surfaces worn by sand grains.
Wire gold (as found in Victoria) is thin cylinders of gold an inch or more long.

Bullion, strictly, is precious metal, refined or unrefined, in bars, ingots, or any other uncoined condition, whether contaminated or admixed with base metals or not. The term is, however, often applied to coin.

Base-bullion is pig-lead, copper bottoms, or pig-copper, obtained in smelting operations and may contain only a few parts per thousand of gold and silver.

Carat is a measure of purity or fineness for gold, pure gold being 24 carat. In the diamond trade, however, carat is used as a measure of weight. The word 'carat' comes from Greek word meaning a carob bean; these little seeds were originally used as weights. In Constantinople the carat used was equivalent to 0.189 grammes and became known as the Graeco-Roman carat. In Syria and Arabia, however, a slightly heavier carob bean, weighing 0.212 grammes, was used, which became known as the Syro-Arabian carat. In 1914 the metric carat of 0.200 grammes was introduced.

Carat gold is gold alloy used in jewellery, and is designated by a *carat number,* i.e. parts of gold in 24 parts of alloy.

Electrum is a very pale yellow natural alloy of gold and silver. Authorities differ on the precise proportions, but it usually contains about 20 to 35 per cent by weight of silver. The name is derived from the Greek word *electron* which also means amber.

Rolled gold is base metal to one or more surfaces of which a sheet of carat gold is attached by soldering, brazing, welding or other mechanical means, and the composite bar reduced in thickness by rolling. It is used in jewellery and is sometimes also referred to as *gold plate* or *gold filled.*

Gold thread is manufactured by the electrodeposition of gold on base metal wire, or cotton yarn coiled with silver wire.

Gold leaf is produced by hammering pure gold to a thin sheet.

Fool's gold is a name for iron pyrites

Purple of Cassius, hydrated stannic oxide containing finely divided gold, is named after A. Cassius who first described its preparation in 1684. It has been used for centuries for preparing purple glass and enamel.

Fabrication is the trade term for all forms of gold processing except the production of bars. It includes the preparation of strip, wire, leaf and chemicals.

Properties

Gold is a very heavy, soft, malleable, ductile, yellow metallic element. It is unusual in that it occurs naturally as the native metal. Natural gold is monoisotopic, but some twenty isotopes can be produced of which the radioactive isotope, Au 198, has some use in cancer therapy and metallurgical research. Gold has a face-centred cubic structure and undergoes no allotropy. Many density determinations have been reported ranging, for example, from 19.21 to 19.4 gm/cm^3 for temperatures near 20°C.

The equilibrium temperature between liquid and solid gold is 1063°C, the highest primary fixed point on the International Temperature Scale.

Resistivities of pure gold have been reported as 2.055 and 2.060 microhm/cm^3 at 0°C and 2.125 at 20°C. At its melting point the resistivity is 6.43 times that at 20°C. Upon melting, the resistivity increases by a further factor of 2.28. The rapid rise in the reflectivity of gold that occurs at about the centre of the visual range accounts for the yellow colour of the metal. The high reflectivity extends into the far infra-red where it is about 98.44 per cent. This property makes gold outstandingly useful in shielding missiles and similar objects against radiant heat from sources at moderate temperatures and gold is widely used for reflectors for infra-red heating. Very thin films of gold upon glass are very effective in reflecting heat, but transmit substantial amounts of green light: such glass is therefore used to reduce the solar heating of buildings. Mirrors coated with gold films by evaporation have many advantages in spectroscopy and astronomy.

The tensile strength of annealed pure gold is very low, values of 1,220 to 1,340 kilogrammes per square centimetre being typical, but it increases at very low temperatures. The yield point is also very low, about 35 kg per cm^2 for extremely pure gold, but it can be raised to about 160 kg per cm^2 by quenching and ageing.

Gold is chemically one of the most inert elements, forming few compounds. Oxygen has no effect upon its high temperature behaviour, distinguishing gold from all other metals and this is the reason for using it in high temperature devices. However, gold dissolves in chlorine water and in hydrochloric acid in the presence of oxidising agents, but it is usually dissolved, as grains or shot, in aqua regia, a mixture of hydrochloric and nitric acids, at moderately elevated temperatures. In the finely divided state, gold is readily soluble in alkali cyanide solutions in the presence of oxygen, and this reaction is the basis of the treatment of South African gold ores, which when introduced made a dramatic improvement in recovery. Sheet or strip gold is used when the metal is dissolved electrolytically.

Red, blue, and violet colloidal gold solutions can be prepared, the colour produced depending on whether the gold salt (usually auric chloride) solution at the time of reduction is faintly neutral or alkaline. The colours are stable, for example they do not change on boiling or standing at room temperature for several months (and are used as part of the decor in some chemist's shops). If a solution of stannous chloride is added to faintly acid, dilute, gold trichloride solution, hydrated stannic chloride is precipitated, which is coloured purple by the gold that is reduced from solution. This precipitate is called *Purple of Cassius* and has long been used as a colouring agent for enamels and glasses.

All compounds of monovalent gold which are not complex are insoluble in water and, with the exception of the cyanide, they are unstable in the presence of water, liberating metallic gold. The cyanides are of great industrial importance in electroplating.

Organic gold compounds, almost all of which are alkyls, have medical applications, e.g. in the treatment of rheumatoid arthritis.

The reaction with organic carbanions such as malonitrile has been utilised in a new method developed by the US Bureau of Mines for extracting gold from low grade refractory carbonaceous ore in which the organic matter is finely disseminated in a clay matrix. Malonitrile extraction was found to be superior to cyanide for this type of ore, but not with oxide ores.

Mineralogy and geochemistry

Economically workable gold occurs mainly in the elemental state and to a lesser extent as tellurides or associated with other ore minerals. Native gold occurs in several varieties with many forms including rhombohedron – like, moss-like and arborescent shapes, plates, skeletal crystals and small particles. It nearly always contains an isomorphous admixture of silver, frequently 10 to 15 per cent by weight. With up to 16 per cent silver, it varies in colour between deep gold-yellow and pale yellow. The specific gravity of pure gold is 19.3, but this is always reduced by impurities. When more than 20 per cent silver is present, the variety is known as *electrum,* which can contain up to 36 per cent by weight of silver, corresponding to a molecular gold to silver ratio of 1 : 1. The colour of electrum varies with the silver content from pale yellow to yellowish white; it has a very high reflectivity and a specific gravity between 15.5 and 12.5.

Küstelite is aurian silver with up to 50 per cent gold.

Gold can form complete series of solid solutions with copper, platinum and palladium. The variety of native gold containing up to 10 per cent by weight of platinum is called platinum gold, *porpezite* is native gold with 5 to 10 per cent palladium, *rhodite* is a variety with 34 to 43 per cent rhodium and aurosmiriditał is a natural alloy of osmium and iridium with about 19.3 per cent gold.

Auricupride is a naturally occurring solid solution of gold in up to 20 per cent copper; *gold amalgam* is a solution of 34.2 to 41.6 per cent gold in mercury; *maldonite* consists of 64.5 to 65.1 per cent gold with bismuth and *aurostibite* is an antimony compound containing 43.5 to 50.9 per cent of gold.

Tellurides are important sources of gold in some localities, e.g. Kalgoorlie in Western Australia: the most important are *krennerite,* with 30.7 to 43.9 per cent gold, which is orthorhombic, and *calaverite* with 39.2 to 42.8 per cent gold which is monoclinic. They are often associated with other tellurides such as the gold-silver tellurides *sylvanite* with 24.3 to 29.9 per cent gold and *petzite* with 19.0 to 25.2 per cent gold. *Aurobismuthinite,* a bismuth sulphide, contains 12.3 per cent gold.

Gold commonly occurs in sulphide minerals, largely if not entirely as the free metal; it is uncertain whether it occurs in true isomorphous substitution and it is very unlikely that gold is present in ionic substitution in silicate minerals, due to its low oxidation potential. As Au^+ has a large electronegativity and would form a very weak covalent bond, gold tends to become concentrated in the residual fluids of a crystallising magma.

The colour of gold in polished section is an index of its purity; nearly pure gold has a yellow colour with a ruby tint and with increasing amounts of silver the colour changes through yellow to pale silvery yellow in electrum. In the Witwatersrand the purity varies from east to west in some deposits from 86.6 per cent to 97.0 per cent. Native gold in siliceous igneous rocks has generally been found to have a purity averaging 97.9 per cent, in intermediate rocks gold-bearing minerals contain 45.1 per cent and in mafic rocks only 24.5 per cent. The purest natural gold, 99.91 per cent, was reported from the Great Boulder Mine near Kalgoorlie. Native gold at the surface and in the oxidised zone is usually purer than that found in the unoxidised zone. Below the oxidised zone the purity seems to be largely independent of depth, although in South Africa small increases in purity with depth have been demonstrated. Purity has been considered by some to provide a sensitive guide to the relative temperature of ore formation, epithermal being 50 to 70 per cent pure, mesothermal being generally 85 to 87 per cent and hypothermal being always over 80 per cent; over 90 per cent results from oxidation. The purity can however vary not only from grain to grain but also within individual grains. In alluvial gold deposits it is quite usual to find grains with margins which have a greater purity than the centre.

Recent work on Mesozoic to Lower Tertiary calc-alkalic batholiths from the Western United States has shown that the highest gold content (as much as 10 parts per billion) occurs in some of the gabbroic and tonalitic rocks of the Southern California batholith. The felsic members of each of the batholiths studied generally contained only 0.5 to 1.5 ppb gold. Basalts from the orogenic belt of the Western United States tend to contain more gold than those of more stable regions of the continental interior, or the oceanic basalts of the Hawaiian Islands. Unaltered rhyolitic rocks are generally low in gold content (0.1 to 1.0 ppb).

The quantity of gold in plant ash (generally less than 1 part per million) has been found to vary from 0.06 ppm in the bark to 0.6 ppm in the interior of the tree in the auriferous region of Guyana, but in Colorado the ash of wood from the interior of large roots was found to contain up to 3 ppm of gold, and ash from the interior of branches contained up to 2 ppm of gold.

Mode of occurrence

Primary occurrences

Gold occurs in many types of rock and in formations of all ages, but the world's most productive deposits are associated with very old rocks and are frequently related to deep crustal fractures. Nearly all gold-bearing deposits occur near acid intrusions, with which genetic relationships can be traced. Gold is commonly found in quartzose veins carrying metallic sulphides, especially pyrites; the country rock adjacent to the vein may also be impregnated. There may be enrichment in sulphide deposits that have undergone weathering, particularly at the boundary between the primary sulphides and the weathered zone which is characterised by red ferruginous deposits, the 'iron hat' or 'gossan' of the Cornish miner.

In high-temperature hydrothermal deposits gold occurs native, often enclosed in host minerals such as arsenopyrite, pyrrhotite and pyrite or combined in tellurides. In middle-temperature hydrothermal deposits native gold predominates but it may also be partly dispersed in sulphide minerals such as pyrite, chalcopyrite, galena and tetrahedrite-tennantite, accompanied by calcite, baryte, dolomite and quartz. Low-temperature hydrothermal deposits with gold commonly contain stibnite, tellurides and chalcedony. As a rule the lower temperature gold deposits are richer in silver.

Gold tellurides are found and worked in Western Australia, California and Colorado, but are comparatively rare elsewhere. The most important gold deposits of the world, the 'banket' of the Witwatersrand in South Africa, are quartz conglomerates containing fine particles of gold that have been subjected to hydrothermal enrichment and regional metamorphism.

Placers

Weathering and erosion liberate metallic gold from primary deposits to form residual stream, beach or marine placers. Gold can be deposited in alluvial gravels mechanically or chemically by encounter with a grain of precipitant or a cross current of a precipitating solution. Placer gold is generally purer than lode gold, the further the placer gold has moved from its source the greater the purity, due to the higher solubility of silver in water; the purity also varies in inverse proportion to the size of the grain. Gold on the surface of nuggets has been found to be purer than in the centre. The purity of gold in placer deposits may be 93 to 95 per cent and lode gold from which it is derived could be about 85 per cent.

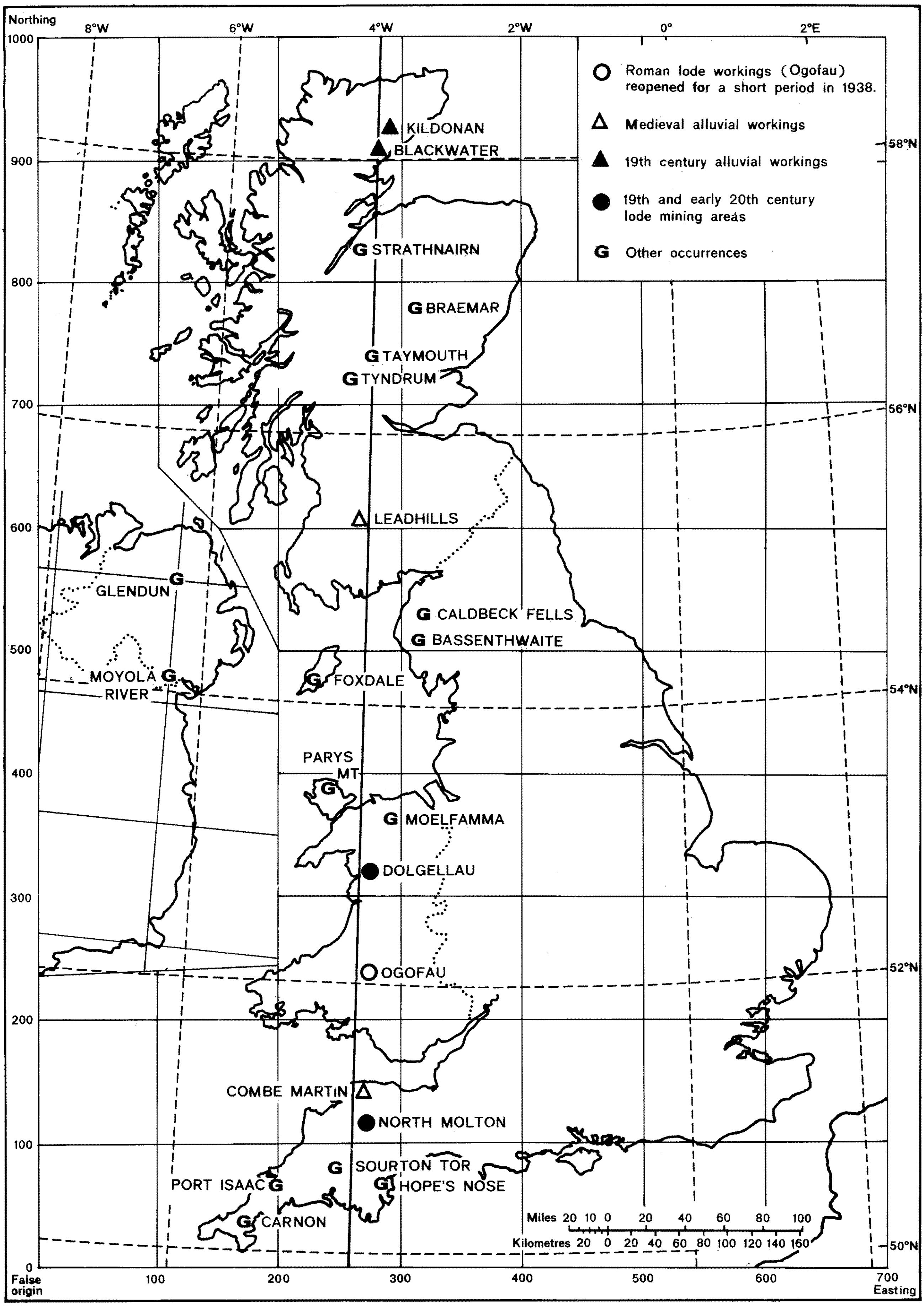

Fig 1 Location of gold occurrences and former gold mining sites in the United Kingdom

Placer deposits formerly yielded by far the greatest part of the world's gold output, but except in the Soviet Union they now supply only a relatively small proportion. Beach and marine placer deposits are of relatively little economic importance. Gold occurs in minute quantities in sea water (about 0.000006 ppm,) but attempts to extract it economically have been unsuccessful.

Resources

The location of the more important of the known gold occurrences and former workings in the United Kingdom are shown in Fig 1. They are all in Lower Palaeozoic or older rocks and stream placers or alluvial deposits derived from them. Except for very minor gold occurrences in Cornwall and Northern Ireland, these deposits are all near the 4°W meridian (and in many of these areas the rivers or streams run more or less north-south). Gold has been worked in Britain at intervals since pre-Roman times, production reaching its peak at the end of the 19th and during the first few years of the 20th centuries. In general only very shallow deposits have been worked. No workable deposits are currently known and no new deposits have been found during the present century. However, as the price of gold has increased over ninefold since British gold deposits ceased to be mined, deposits below abandoned workings, or low grade deposits with no visible gold, may now be of economic importance.

South-west England

Gold occurs in several areas in south-west England and has been mined in small quantities at irregular intervals, notably in the 19th century. The presence of gold in Cornish tin streams appears to have been known to the Romans, and possibly to the Iberians and the Phoenicians. In 1338 a comptroller named Suthrop was appointed warden of the gold and silver mines in Devon and Cornwall. For many centuries small quantities of gold were collected by tin miners without attracting particular attention. Elizabeth I consigned Cornish gold and silver mines to patentees of the Mineral and Battery Works, later incorporated as the Mines Royal Company.

Gold is reported to have been obtained in Cornwall from tin streams, copper ores, lead ores, pyritic and gossan ores, and from granite. Most of the tin streams flowing south have yielded some gold, the Carnon stream at the head of the Restronguet creek in the Falmouth estuary being probably the richest. In northern Cornwall, alluvial gold has been reported to occur at Port Isaac, associated with antimony. The antimony sulphides of the Wadebridge. district, notably the Treore mine, 2.5 km ESE of Port Isaac, are auriferous and nearby alluvials have yielded a little gold. Gold is reported as having been found in veins in granite at St Just, West Cornwall. There has been no recorded Cornish gold production for many years.

In medieval times Devon appears to have been the most important area of gold production in England. The earliest legal reference to gold is in a writ of 1263 by which the sheriff is required not to allow gold and copper mines to be occupied until the king shall give orders. 300 to 400 miners were employed at Combe Martin during the reigns of Edward I (1272-1307) and Edward III (1327-1377). Grants to prospect for gold and silver in Devon were made in 1319 and 1322. A number of other medieval royal grants of gold mines in Devon were made, particularly during the 14th century. Devon is included in the general grant of gold mines to the Mines Royal Company made in 1576 by Elizabeth I. In 1852 the gossan ores of the Britannia iron mine and the Poltimore copper mines in the North Molton area of North Devon were discovered to be worth working for their gold content. The first yielded about 824 grammes of gold from about 20 tonnes of ore. The total quantity of gold obtained from 1852 to 1853 was about 4.7 kg (152 oz) then worth £4.20 per ounce. The auriferous gossan lode was 1.2 m to 3.0 m wide, dipping to the north: it was a friable ironstone containing copper formed by the decomposition of slightly auriferous metallic sulphides, mainly iron pyrites. Small particles of gold were reported as visible in the somewhat siliceous ironstone, which was brown on the western side of the river Mole and reddish on the eastern bank, where the gold content was reported to be higher. Pyrite and pyrrhotite concentrates representing 7 to 8 per cent of the samples from boreholes drilled by the IGS at Sourton Tors near Okehampton in 1969 contained up to 40.2 ppm of gold. Small amounts of alluvial gold have recently been found in stanniferous gravels from streams flowing southwards off Dartmoor. Small quantities of native gold have been found in South Devon about 2.5 km south of Torquay in a crush breccia filling an east-west fault in Middle Devonian limestone at Daddy's Hole and small quantities of dendritic gold have been found in narrow calcite veins at Hope's Nose, 3 km south-east of Torquay.

Somerset is referred to in a writ on gold mines in 1374, the 47th year of Edward III, issued to William Nottingham. Other grants relating to gold mines in Somerset were issued by later monarchs, but Somerset does not appear to have been important as a gold producer in the Middle Ages. The gold was probably extracted from sulphide, mostly lead, ores, rather than as native metal: Sir John Pettus in his Fodinae Regales in 1670 expressly includes Somerset as having copper mines containing some gold and silver. Gold was reported many years ago in the Golden Rake in the Mendip Hills but there are no recent references. Carboniferous limestone taken from a quarry in eastern Somerset at Whalton near Clevedon in 1876 was reported as containing up to about 25 grammes of silver and about 0.2 grammes of gold per tonne. Some caution is however expressed in the literature as to the reliability of the analysis. The Exmoor region of western Somerset may be auriferous as there are haematite deposits somewhat similar to those in the North Molton district of Devon. Gloucestershire attracted some attention as a gold district during the Middle Ages. During the reign of Elizabeth I, Gloucestershire was listed in a grant to Houghsetter and Thurland, and it was one of the counties where the Mines Royal Company exercised its monopoly as to gold. In 1907, Old Red Sandstone conglomerate assaying 0.38 grammes of gold per tonne was reported about 2 km south-west of Mitcheldean in the Forest of Dean and the Charston Syndicate Limited, formed in November 1906 to develop this prospect, was wound up in September 1908, the venture being a failure.

Midlands

A siliceous rock taken from a roadstone pit at Bromsgrove Lickey near Birmingham in 1864 was reported to contain gold and silver, but it was not at the time found to be profitable to treat the material. No later references to the occurrences have been traced. A grant to Houghsetter made in 1565 by Elizabeth I refers to Worcestershire as one of the eight select counties in England rich in gold, silver and copper. Writs issued during the 7th and 34th years of Edward III refer to mines of copper mixed with gold and lead in Shropshire (Salop). Sir John Pettus referred to a rich copper mine working in the 17th century at Eardston near Oswestry.

Lake District

Ancient copper workings in Goldscope, Vale of Newlands, south-west of Keswick, may have been worked for gold by the Romans, but the first published reference to gold in Cumberland (Cumbria) is in the reign of Elizabeth I. She resumed the mines of Keswick on account of their containing gold and silver and granted them to Houghsetter and so to the Mines Royal Company as reported in Plowden's account of the trial between the Queen and the Earl of Northumberland. In recent years the British Museum (Natural History) has been given small gold specimens from a considerable number of localities in Cumberland.

Wales

Most of the gold mined in the British Isles has been won from the Dolgellau gold belt in Gwynedd. During Roman times there was open pit and underground mining for lode gold in Dyfed, South Wales, but there is no recorded gold mining in Wales during the Middle Ages, although some may have been recovered from the silver extracted from lead ores, the production of which was highest during the 19th century.

The Ogofau mine near Pumpsaint, some 11.3 km south-east of Lampeter, in Dyfed, shows evidence of relatively large-scale open-cast and shaft mining from about 200 to 375 AD. It lies on the western limb of the major south-westerly trending Cothi-Rhiwnant anticline within a zone of severe crumpling and associated thrusting developed at or near the Ordovician-Silurian junction. Natural rock exposures within this area are limited, but the known extent of mineralisation is defined by alignments of open-cast workings and adits extending along the strike for 1,097 metres. Mixed sulphides carrying gold are found in quartz bands which conform with several folds plunging steeply to the west. The most recent mining venture, which ceased in 1939, proved that two of these quartz bands continued to about 305 metres on incline from the original outcrop. The ore stoped from the upper of these two quartz bands, the so-called Roman lode, yielded about 6.1 grammes of gold per tonne and exploration within the underlying band, or Pyritic lode is said to have indicated similar values. Because of the somewhat limited coverage of exploratory boreholes and the possibility of repetition as a consequence of faulting, it was not fully determined whether the lower 61 metres in the zone of crumpling contained a further two bands of auriferous quartz. In mid-Wales at Cwmystwyth, the Kingside lode on Copper Hill has been reported to contain zinc blende, galena and 4.6 grammes of gold per tonne.

The most important known occurrences of gold in Wales are in the Dolgellau gold belt where the country rocks belong to the lower two of the three sub-divisions of the Lingula Flags (Upper Cambrian), namely the Ffestiniog Beds and the Maentwrog Beds, and the upper part of the underlying Menevian Beds (or Clogau Shales) of the Middle Cambrian. Gold-bearing veins have not been found at geological horizons lower than the Clogau Shales. The total thickness of Cambrian sediments known to be intersected by gold-bearing lodes amounts to about 1,100 metres. The auriferous quartz veins run approximately east-west and almost all are intimately associated with minor greenstone intrusions (assumed to be Ordovician). They invariably occur underneath black carbonaceous shales or cleaved mudstones rich in pyrites, which probably controlled the precipitation of gold from ascending solutions. Adjoining lodes varied greatly in richness and even in the same lode the distribution of the gold was very capricious. The lodes are normally steeply inclined and are locally displaced by north-south faults.

The gold was normally coarse, granular or aggregated, or more rarely was finely disseminated through the quartz. In addition to gold, some of the lodes contained varying amounts of pyrite, pyrrhotite and chalcopyrite, together with minor quantities of galena, zinc blende, arsenopyrite and in some lodes cobalt, nickel and bismuth minerals (including tetradymite, bismuth telluride).

The Clogau mine, north of Bontddu and west of Dolgellau (Gwynedd), and the nearby Vigra mine (named after the Phoenician sun god and, perhaps, worked in pre-Roman times), both originally worked for copper and worked together from 1900-1905, as the St David's mine (by the St David's Gold and Copper Mines Co Limited), was the main producer. The Clogau lode is almost vertical and strikes nearly east-west. It is close to the contact between the Maentwrog slates and the underlying Lower Cambrian sandstones, and varies in width between 0.6 and 2.7 metres, but it is split in places. The gangue is quartz, whitish and chalcedonic in appearance. Of the sulphide ores found in depth, blende is by far the most abundant, but considerable quantities of pyrite, pyrrhotite, chalcopyrite and arsenopyrite also occur. The gold is occasionally found in the clean white quartz, but more often it is in a darker veinstone or associated with blende. The values are erratically distributed, with richer shoots and pockets.

Gwynfynydd, the second most important Welsh gold mine, 10.5 km north of Dolgellau, was opened for lead. The auriferous character of the lode was first discovered in 1864, when a small pocket of gold was found about a metre below the surface; exceptionally, some of the ore yielded from 169 grammes to 395 grammes of gold per tonne. The Gwynfynydd lode strikes east-west and consists of opaque white quartz much mineralised with sulphides, the gold being usually more finely divided than in the St David's lode at Clogau. In 1895 the mine was operated by British Goldfields Co Limited, but was acquired by St David's Gold and Copper Mines Limited in 1910. Operations ceased finally in 1938.

The lode in Carn Dochan mine, 8 km south-west of Bala (Gwynedd), consists of extremely clean quartz with finely disseminated specks of gold and occurs in soft black Ordovician shales near their junction with beds of felspathic ash and lavas.

Prince Edward mine, 3.2 km north-east of the village of Trawsfynydd (Gwynedd) worked a gold-bearing vein, also containing galena, sphalerite and chalcopyrite, which traverses Upper Cambrian (Maentwrog Beds) shales and flags with associated greenstone intrusions. Prysor, a small mine 8 km east-north-east of Trawsfynydd, worked a wide lode and associated minor veinlets within the Upper Cambrian shales, mainly for copper.

Alluvial gold has been obtained from the sands of the river Mawddach. The gold recovery techniques used were not efficient by modern standards and appreciable quantities of gold may remain in the alluvial sands and gravels in the valley, estuary and, perhaps, in nearby marine deposits in Cardigan Bay. Proposals for dredging in the Mawddach estuary were abandoned in 1972, mainly on account of environmental objections.

In about 1889 shafts and levels were driven into the rocks of a small Silurian infold at Rhosmynach-fawr in Anglesey, and chalcopyrite was obtained; when the abandoned mine was reopened in about 1918 a small amount of ore yielding an average of 15 grammes of gold per tonne was found in lenticular aggregates along the cleavage planes of altered shale. The ore consisted of an intimate intergrowth of pyrite, chalcopyrite and fibrous quartz: bismuthinite and tellurides are also present. No gold was visible under the microscope. A partial analysis of a selected specimen was:

SiO_2	28.8 per cent
Fe	21.0 per cent
Cu	5.6 per cent
Bi	8.5 per cent
Ag	6.00 oz per ton (183.67 gm/tonne)
Au	13.65 oz per ton (417.86 gm/tonne)

Gold and silver have also been recorded at Parys Mountain, Llangaffo and Bonw in Anglesey. The gold is probably contained partly in the silver and partly in pyrites.

Camden, the Elizabethan chronicler, in his celebrated work 'Britannia', affirmed that gold was sought and found in Flintshire (Clwyd). Within the Clwydian Range at least eight groups of small shafts, levels and associated trial diggings have been sunk or driven in search of gold-bearing quartz veins in Ludlow Beds (Silurian) comprising mudstones or shales and fine-grained grits or flags. These trials are north and north-east of Moel Fammau within 4.8 km of the highest point of the Range. The veins appear to be associated with SW-NE faults and lesser fractures of NW-SE trend. Information on the workings is very scanty.

Scotland

The most important occurrences of gold in Scotland are in the Southern Uplands, particularly as alluvial gold near Leadhills and Wanlockhead, where lead has been mined for centuries. The sporadic occurrence of alluvial gold in upper Clydesdale has long been known. The oldest rocks of the area are pillowy diabase-lavas with overlying radiolarian cherts of Lower Llandeilo age in a series of isoclinal folds. Overlying the cherts is a well defined but thin bed of black shale, the Glenkiln shales, of Upper Llandeilo age, followed without any stratigraphical break by the Hartfell shales of Caradoc age, which in the Leadhills area give place to coarse greywackes, grits and conglomerates. Some, but not all of the metalliferous veins run more or less north-south. The galena veins of the Leadhills are only developed in these arenaceous sediments. Production of gold has been from river alluvium and glacial till on hillsides. *In situ* occurrences of gold in mother lodes are very rare.

During the reign of James IV gold deposits were discovered on Crawford Moor, Lanarkshire (Strathclyde), and were worked by Sir James Pettigrew from 1511 to 1513. Operations then ceased for a couple of years, probably because of the military defeat at Flodden, but started again in 1515. From 1570 onwards Elizabeth I patronised the Clydesdale diggings. Mr (afterwards Sir) Bevis Bulmer worked alluvial deposits in the Leadhills area between 1578 and 1592, particularly in the valley of the Elvan Water, a tributary of the Upper Clyde. A nugget found in 1502 was said to weigh 27 oz (0.8 kg) and appears to have been about 22 carat gold. A brown iron ochre, probably a gossan derived by alteration of auriferous pyrites, from the Soar Burn on the upper waters of the Wanlock was reported to yield more than 7.7 grammes of gold per tonne. A little gold is reported to have been obtained from the headwaters of the Annan, particularly tributaries of the Moffat Water. A sample of pyrites from an 18th century working at Torbookhill, near Annan, is recorded as yielding 6.1 grammes of gold and 306 grammes of silver per tonne. A quartz vein containing gold was found at Wanlockhead in

1803 and another was reported to have been found in the Lowther Hills in 1970.

In the north of Strathclyde a pyritic schist with small amounts of gold, silver, galena and blende occurs in the Ardrishaig phyllite on the shore of Loch Fyne. A composite metallic lode discovered early in the present century at Stronchullin was reported to have assayed 31 and 155 grammes per tonne respectively of gold and silver.

Gold was worked in the Borders during the 16th century. At the beginning of the 16th century a nugget weighing nearly one kilogramme was said to have been found in Ettrick Forest in the Glengaber Burn, a tributary of the Meggat Water which flows into St Mary's Loch. Gold dust and granules are reported to have been obtained from the St Mary's Loch district. The headwaters of the river Tweed, particularly the Mannor Water, are also reported to have yielded a little gold.

Gold was mined in the 16th century near Linlithgow, West Lothian, and during the 18th century associated with silver in the south of the Ochil Hills, near Alva.

A nugget weighing over 60 grammes was reported to have been found many years ago near the headwaters of the river Tay in Breadalbane and in 1861 gold was found associated with iron pyrites in vein quartz at Taymouth near the east end of Loch Tay. At Lochearnhead it is reported that arsenical pyrites yielded gold at the rate of about 180 grammes per tonne and particles of native gold were visible in the gossan. Ancient documents suggest that gold was once worked in Glen Clova at the head of the South Esk.

A 16th century document by Atkinson reprinted in 1825 recorded a gold mine owned by Lord Glames at Overhill in the parish of Belhelvie. Small quantities of alluvial gold have been recorded from tributaries of the river Dee, at Braemar and Invercauld, and in beach sand near Aberdeen. There have been a few minor reports of small quantities of gold having been found in the Grampian Highlands during the 20th century.

Alluvial gold occurs in both the south and the north of the Highlands. Small quantities of gold dust were reportedly found in 1869 in the alluvium of the headwaters of the Errich and Nairn rivers in north-east Inverness-shire and a reported discovery of gold dust inside geese from Inverness-shire aroused considerable local interest in 1971.

The ancient Pictish towers and brochs of Sutherland have been interpreted as a means of defence for gold diggers against marauding bands of maritime rovers attracted to the area by the report of gold. The small forts are particularly numerous in the immediate vicinity of the Suisgill and Kildonan streams which are the most highly auriferous in the district. The country rocks where the alluvial gold has been found in south-east Sutherland and western Caithness consist primarily of Moine sediments which are strongly injected by granite. The source of the gold has not yet been traced but it is probably in the peat covered moorland near the boundary between Sutherland and Caithness. The occurrence of gold was reported in Caithness and Sutherland in the 16th century, but attracted little attention until 1868 when a native of Sutherland, Mr R N Gilchrist returned from Australia where he had been a successful gold digger. In November he led a search for gold, which was soon found in the Kildonan burn, a small tributary of the Helmsdale river, which flows through the Strath of Kildonan to reach the coast at Helmsdale. About 1869 gold was also discovered in smaller quantities in the Allt-Smeoral or Gordon-bush burn and in the Uisge Duibh or Blackwater, two streams which enter the head of Loch Brora, about 8 miles south-west of Kildonan on the far side of the watershed of the Helmsdale river.

During 1868 and 1869, there was a minor gold rush with about 400 men digging near Kildonan. Each digger paid a licence fee of £1 a month and a royalty of 10 per cent to the Duke of Sutherland. The quantity of gold produced has been disputed. Although royalty was paid on only £3,000 worth of gold, according to Dr L Lindsay about £15,000 worth of gold was actually obtained and purchased, mainly by Mr P G Wilson of Inverness, initially at £4 per ounce, but falling to £3.50. Gold digging in the Brora district was prohibited from 1 January 1870 because the licence fees obtained did not compensate for the damage caused to pastoral interests by driving sheep away from the sheltered valley to the bleak mountainside. In 1896 the Sutherland County Council endeavoured to re-open the diggings in a Helmsdale tributary, and set several men to work in the Suisgill burn, but the venture was not profitable. In 1964 the Institute of Geological Sciences found a rather irregular distribution of gold in sediments from streams draining the north-east flanks of Strath Kildonan and a small amount was also obtained from a minority of samples of decomposed granite. In the course of regional geochemical investigations in eastern Sutherland and Caithness in 1969, the IGS established the presence of gold outside the previously known localities. Although widespread, the gold content of the alluvium of the Helmsdale river was then considered to be below the economic level. Gold may occur in sand and gravel deposits off the mouth of the Helmsdale river adjacent to the coast of Sutherland and Caithness, but extraction would probably only be profitable as a by-product of marine sand and gravel extraction.

The earliest record of the discovery of gold in Scotland was in 1245 when Gilbert de Moravia is reputed to have found gold in Durness, a few miles south-east of Cape Wrath, but there have been no subsequent accounts of gold from this area. In 1904-5, trials were made on a band of rock in Lewisian gneiss near Dornie, Loch Duich, Ross-shire, rich in pyrites and pyrrhotite said to contain traces of gold, although later work has not verified its presence.

Isle of Man

Very small quantities of gold have been reported to have been found in quartz veins and slates adjacent to the Foxdale granite. (The galena mined at Foxdale was rich in silver but no gold content was reported.) The Onchan (Douglas Bay) graphite mine yielded ore containing several grammes of gold per tonne of ore.

Northern Ireland

In Northern Ireland gold has been reported in alluvium derived from Dalradian rocks in the River Moyola, Co Londonderry. More recently it has been found in gravels at the confluence of the Glendum and Owenagluish rivers, 6.4 km west of Cushendall in Co Antrim. Only very small quantities of gold have been obtained and neither occurrence has been investigated in detail.

Uses

Monetary

Most of the world's gold is held by governments and central banks, mainly in the form of bars, to provide stability for paper currencies: until fairly recently, most international trade balances were settled by the movement of this gold. Standard delivery gold bars are produced by a small number of refineries throughout the world; they vary slightly in weight, South African bars generally weigh 405 to 410 troy ounces (12.60 to 12.75 kg) and standard bars produced in the Soviet Union usually weigh 380 to 395 troy ounces (11.82 to 12.29 kg). Each bar has to bear the stamp of an acceptable melter and assayer: the minimum purity for monetary gold is 99.5 per cent. South African bars are usually 99.6 per cent pure but Soviet gold bars are 99.99 per cent. The standard gold bars held by central banks measure 175 x 90 x 40 mm and weigh about 400 oz (12.44 kg). The US Federal Reserve Bank is reported to hold about one million of these ingots.

Commercial tablets gold

In addition to standard bars for international monetary transactions, small ingots known as tablets are used for commercial trading, investment and hoarding. These tablets are frequently much smaller: a favourite size is the 'ten tola' bar weighing 3.75 oz (116.6 gm) produced both in England and Switzerland, largely for the Indian market, although this trade has decreased following the recent major increase in the free market price of gold. A specially high surface finish is preferred for gold tablets produced for private use.

Legal tender coin

No fewer than 108 major varieties of sovereign issued since 1838, as well as half sovereigns, two pound and five pound coins, are still valid as legal tender in the United Kingdom for any amount (Coinage Act 1971 s2(i) a). However, gold coins disappeared from general circulation in Great Britain during World War I, when they were replaced by Treasury notes, as their value as collectors' pieces and their intrinsic value greatly exceeded their nominal face value. In most years between 1838 and 1917 over a million sovereigns were struck by the Royal Mint, the peak production years being 1911 and 1912 in each of which over 30 million were struck. During this period, 6,220 tonnes of gold were transformed into coin by the Royal Mint, mainly in London, but also at branches in Sydney (1871-1926), Melbourne (1872-1931), Perth (1899-1931), Ottawa (1908-1919), Bombay (1918 only) and Pretoria (1923-1932). The standard weight of the sovereign is 7.98805 grammes, the least weight is 7.93787 grammes and the fineness is 22 carat (916.66 parts in 1,000 pure gold).

By section 8 of the Coinage Act 1870 'where any person brings to the Mint any gold bullion, such bullion shall be assayed and coined and delivered out to such person, without any charge for such assay or coining or for waste in coinage.' Except for gold bullion brought to the Mint by the Bank of England, this section was repealed by the Gold Standard Act, 1925, which also suspended the use of gold coin for internal circulation and restricted the holding of gold coins. In 1966 it was made illegal for United Kingdom residents to continue holding more than four gold coins minted after 1837, or to acquire such coins unless licensed as genuine collectors by the Bank of England. These restrictions were lifted in 1971. From April 1975 gold coins minted after 1837, including medallions, could no longer be bought from non-residents except by authorised dealers who could sell only to non-residents, importing being subject to individual licensing. No restriction was imposed on holding gold coins already in the United Kingdom, and collectors were not required to register or to obtain permits. 14.7 tonnes of gold were converted into legal tender coin in the United Kingdom in 1974 compared with only 0.7 tonnes in 1973.

British gold coins worth over £93 million were melted down in 1930 by the Royal Mint and converted into standard bars for the Bank of England. Between 1957 and 1968 gold sovereigns were again minted in quantity (over 8 million in 1958 and over 4 million in 1968) in the United Kingdom for sale on the international market, and to counteract the activities of counterfeiters. There is a considerable demand for sovereigns in many countries; they are used for example in Greece for the purchase of land and the payment of dowries. There are, however, 34 types of sovereign which are known to exist in counterfeit form, some of standard weight and 22 carat fineness, a few even of greater purity, but many are seriously impure. Private mints in Switzerland and the Lebanon have produced gold coins closely resembling famous coins whose market value greatly exceeds their nominal face value. The great popularity of gold coins for collectors has stimulated some governments to issue gold coins for the first time. The Isle of Man issued a set of legal tender gold coins in 1974, consisting of five pounds, two pounds, sovereign and half sovereign. The Royal Silver Wedding anniversary in 1972 was commemorated in Jersey by the production of five gold coins declared to be 'legal tender coin' but not available for general circulation; they include a 50 pound piece. Malta has also recently issued a set of gold coins. The Royal Mint is also permitted by statute to strike coins for other countries; for example 18 million gold lei were struck for Romania in 1928 and 46,300 gold pieces for Egypt in 1930.

The Krugerrand is a 22 carat coin of current legal tender in South Africa and it contains exactly one fine ounce troy of pure gold (this is embossed on the coin instead of a face value). It was first minted in November 1970 and quickly became popular, particularly within the European Economic Community, where it is not subject to value added tax. Monthly overseas sales of Krugerrand (issued at a surcharge over the value of the gold content) by the South African authorities rose sharply during 1974 from 21,000 coins in January to 341,000 in December. 99.7 tonnes of gold were converted into legal tender coin in South Africa in 1974

The gold standard

Great Britain adopted the gold standard in 1816, Germany in 1871, followed soon by the Scandinavian countries, but by the USA only in 1900. Under this monetary system gold coins were in general circulation, notes and bank deposits were freely convertible into gold, the export of gold was not restricted, and the Royal Mint was open for the free coinage of gold. A country on the gold standard whose reserves in gold or foreign exchange were reduced to their minimum possible level had either to produce more gold or restore the balance of its foreign payments. The gold standard with full convertibility in gold has been regarded by some as the only international monetary system that does not generate inflation and deficit in the balance of international payments.

In the United Kingdom the full gold standard was suspended in 1914 and gold coins disappeared from circulation, to be replaced by Treasury notes. Before 1914 there was a legal minimum of gold cover for the currency, fixed on the basis of the amount of gold issue. Subsequently this reserve ratio was calculated on the figure of the note issue plus 'sight' liabilities and this principle was embodied in the banking legislation of several countries. After 1920 some countries formerly on a silver basis, or which had inconvertible paper currencies, went over to the gold standard and further increased the scarcity of gold.

In 1919 the United Kingdom prohibited gold exports. In 1925 the United Kingdom adopted a 'gold bullion standard' (under which the use of gold coin for internal circulation was definitely suspended), the prohibition of gold exports was removed, and the Bank of England was required by statute to buy gold at £3 17 9d a standard ounce and foreign holders of sterling were entitled to buy gold bars from the Bank of England at its official selling price of £3 17 10½d a standard ounce, for shipment overseas or for keeping on deposit with the Bank. A number of countries adopted a system known as the 'gold exchange standard', under which Central Banks, instead of building up large gold reserves of their own, accumulated foreign exchange reserves mainly in currencies on a gold basis, particularly sterling and US dollars. The Central Banks were buyers of dollars or sterling whenever an excessive supply tended to cause an undesirable appreciation of the national currency, and they became sellers whenever an excessive demand threatened to cause a depreciation. In the inter-war period most countries, but not the USA, admitted some restrictions to the full application of the gold standard.

It has been held that the present world production of gold is too small to allow it to serve as a standard for world trade. In the summer of 1972 the President of the United States suspended the convertability of the US dollar into gold and there are now only two countries remaining on the gold standard, Switzerland and the Soviet Union. Gold is no longer a standard of value for commodities, but it still serves as a link between the values of currencies of the International Monetary Fund.

Jewellery

Gold has the unusual property of being resistant to tarnishing, but to improve its resistance to wear, to give it better working properties and to lower the cost, it is usually alloyed with other metals. The system of standardising gold alloys in relation to the carat, a proportion of a twenty-fourth, has been used for centuries.

To harden gold for use in jewellery, small quantities of less expensive metals are added. These additions modify the colour and may be added for this purpose, thus copper produces reddish alloys, silver produces greenish to white alloys and when copper and silver are added together the resulting alloy has a rich yellow colour. In the lower carat qualities, the colour is improved by the addition of zinc. Palladium and nickel may be added to produce white gold alloys now in demand as a substitute for platinum in modern jewellery.

Wedding rings have usually been made of 22 carat gold, those of the Royal family being made from gold mined in Wales. Much of the best jewellery, and almost all gold watch cases, are made of 18 carat gold as the beauty of its colour is little altered by wear. 15 carat gold is used extensively for 'coloured' jewellery as it is durable and strong and 13 carat gold is the lowest quality that can be readily coloured to look rich and beautiful. 9 carat gold is now used extensively for cheap jewellery although it is not recognised as gold in some countries (for example the USA where 10 carat or 416 fine is the minimum requirement for jewellery described as gold). Rolled gold used in some jewellery and spectacle frames is made from a base metal, brass, bronze or nickel, clad with 12 or 14 carat gold alloy. The composite is then rolled or drawn. Some jewellery and plate ornaments are gilded, either chemically or by electroplating; the gold coating used is generally much thinner than that on rolled gold objects.

Textiles

The manufacture of gold wire goes back several thousands of years; it is in cloth worn by the Ancient Egyptians. The use of gold thread became widespread in India during the Mogul Empire and travelled west via the Moors to Italy, Germany and France. The manufacture of gold thread in Europe developed before 1914 and threatened the Indian industry. At one time there were four small factories in London and three in Preston making gold thread or gold lace, but the main centres were Lyon and, to a lesser extent, Nurnberg and other Bavarian towns. Originally only pure gold was used, but this had been largely replaced by cheaper products, gold plated silver wire and thread and, more recently gold plated copper wire. Gold thread consists of flattened wire which is spun round cotton or silk yarn and is used mainly in laces and braids.

The ability of gold and some high gold alloys with platinum or rhodium to resist the simultaneous action of caustic soda and sulphuric acid was first utilised during World War II for the spinnerets (spinning nozzle tips) used in viscose rayon synthetic fibre production.

Ceramic and glass ornamentation

Gold is widely used in the production of both red and purple underglaze colours for the decoration of porcelain. These must resist reacting chemically with the glaze during the kiln firing and for this reason the purity of the materials used is particularly important. The main gold chemical used is gold trichloride prepared from purified gold (as ordinary commercial gold is not pure enough) to which various other chemicals are added to modify tones. According to the mode of preparation a range of very handsome underglaze colours from dark purple to delicate rose red can be obtained.

Gold is also used in red and rose-red to purple glazes which are fired in muffle furnaces at relatively low temperatures. Bright gold surface ornamentation on ceramics and glass can be obtained by applying 'liquid bright' gold preparation to the surface prior to firing. This preparation contains about 12 per cent of gold and up to 1 per cent of rhodium dissolved in sulphurised Venice turpentine; small quantities of oxidisable metals such as bismuth, tin or vanadium are added to bond the film strongly. The rhodium is essential to produce a smooth lustrous film. A firing temperature of at least 540°C is normally used and the gold film produced is about 0.1 microns thick. This film may be increased later in thickness by electroplating but this is expensive. To economise in the use of gold and to produce the appearance of heavy gilding, the parts to be coated with gold may be first painted with yellow colour. Burgess lustres, beautiful rich reddish lustre effects, are produced on porcelain by use of bright gold associated with bismuth lustre. Ordinary gold fired with a glaze is always dull with little metallic lustre. In order to obtain the maximum lustre possible, the surface must be burnished after firing, first using an agate burnisher and finally with a bloodstone. The heavy pressure applied by the burnishers flattens and unites the small particles of gold to form a coherent sheet of metal. Pure gold when burnished has a reddish tone; the addition of small quantities of other metals alters the colour, for example platinum produces a gold red and silver a gold yellow. Matt gold can be produced by adding a mixture of finely divided gold and silver to the surface and firing at a high temperature without a flux.

Perfectly transparent glass of exactly the same tint as ruby can be prepared by dissolving gold in molten glass, 1 part of gold in 50,000 parts of glass producing a deep ruby glass and 1 part in 100,000 producing light red glass. The solvent capacity of glass for gold is very limited. If more than 1 part in 50,000 is added the excess of gold is left as a fused button in the bottom of the crucible. Ruby glass is used in jewellery and in stained glass, and ground to a powder it can be painted on porcelain for red decorative effects.

Electrical and electronics

The main industrial use for gold is in electrical contacts, and is due principally to the immunity of gold to the formation of high resistance films of oxides, sulphides, or organic material. Other factors are the good electrical conductivity, low modulus of elasticity and the low yield point of pure gold, which ensure a low and constant resistance.

Gold is used on contacts in both wrought form and as electrodeposits. Alloys used include those with 3 per cent zirconium, 20 per cent silver, 3 to 5 per cent nickel (for currents less than 0.1 amp) and 10 per cent platinum (for currents including high frequency up to 1 amp). Other alloys used for electrical contacts are gold with 3 per cent cobalt and up to 16 per cent nickel. The welds at the ends of spring members of relay and connector contacts are usually 18 carat, using gold-silver alloy. Cladded gold alloy 'stripes' on sheet materials, such as copper-based spring materials, are of growing importance.

Solid gold localised at the mating site of the contact member reduces the amount of gold otherwise necessary. Monolithic gold alloy contacts are also employed in slip ring brush systems. The ease with which gold can be applied to base metals in the required thickness by electrodeposition reduces the cost to the minimum consistent with the required corrosion and wear resistance, which had led to a substantial use of gold in plug contacts and printed circuits. Where hard materials are required for superior wear resistance or to provide good spring properties and fatigue strength, a number of hard gold electroplates and gold alloys are available, some of which can be further hardened by heat treatment.

Electrolytes of many kinds are now available to provide high purity or alloyed gold deposits of good ductility and low porosity for contacts, edge connectors, for printed circuit boards, semi-conductor devices and other electronic assemblies. Soft deposits of nearly pure gold are used to provide clean, tarnish-free surfaces on parts which are to be joined by thermal compression bonding or solderless wrapping, or which are required to retain their solderability during extended storage. Harder deposits, usually containing up to 1 per cent of silver or cadmium, are widely used in the separable connectors known as 'dry contacts' needed in sophisticated miniaturised electronic equipment, where voltages, currents and contact forces are usually insufficient to cause electrical, thermal or mechanical breakdown of any tarnished film that may form. The porosity of these immaculate gold surfaces at the heart of all electronic circuits is very important as wherever there is a pore below the gold coating there is a possibility of the underlying metal being attacked, and the corrosion products may spread out over the gold surface. The necessary dense, bright, relatively pore-free coating of gold plate is generally produced by electrodeposition. Some small electronic components are plated by replacement plating by which the gold is deposited to a thickness of about 0.00005 mm from an alkaline cyanide solution. This technique can provide a uniform coating even over intricately contoured surfaces, but as the gold film may be microporous, thicker films of at least 0.005 mm are necessary for full protection.

A small but important application for gold is for sliding contacts, such as instrument slip rings and in-plug connectors where appreciable sliding is involved, although wear may occur by adhesion, abrasion or brittle fracture. Wear by adhesion of unlubricated sliding contacts can be minimised by using either a rhodium-plated surface or gold alloys (with 0.15 per cent nickel, 0.1 per cent cobalt or 2.5 per cent cobalt) which are harder than pure gold, for one side of the contact. Some electrodeposited gold alloys have been found to be unusually resistant to wear in instrument slip rings which slide for long distances, either continuously or intermittently.

A small but very important use of gold is for more or less stationary contacts with carbon where, because of the high resistivity, hardness and low thermal conductivity of carbon, contact areas may become quite hot; base metal connections would oxidise, introducing intolerable electrical noise in the circuit. For example, the contact surfaces in telephone transmitters are coated with a very pore-free gold electroplate and a thin layer of gold is applied near the ends of ultra-reliable pyrolytic carbon-coated resistors for missile use. Gold appears to be immune to the formation of minute metallic whiskers which can cause much trouble in small low current devices. In general, gold contacts are used when extreme reliability is required, long term storage is likely and only a limited number of operations is anticipated, as in defence equipment.

A gold alloy containing 2 per cent chromium is used for standard resistances. It has advantages over manganin (an alloy of copper, manganese, nickel and iron) by having a lower temperature coefficient of resistance and attains constant resistance much sooner. The standards have to be sealed in argon-filled enclosures, as the alloy changes in resistance with humidity variations. The same alloy is also preferred to manganin for high pressure gauges because of its lower temperature coefficient of resistance. A very simple and convenient method of protecting electric furnaces from damage is by means of a metal fuse which will melt and cut off the power supply if overheating takes place. Gold-palladium alloys are widely used, as they have a short melting range and high resistance to oxidation and deterioration. Gold-palladium alloys can be selected to give protection in the range 1,100°C to 1,500°C.

Gold brazing alloys are used extensively in the construction of electronic devices where melting temperatures above the usual silver-copper-base-alloys are required. The higher melting alloys of the Au-Ag, Au-Cu and Au-Ni series enable successive brazes to be made in assembly without damage through the remelting of previously made joints. Joints may be made by diffusion bonding, a method which makes use of the softness of gold and the absence of oxide formation. Gold or copper-gold alloy is placed between two copper or copper-plated surfaces which are held in intimate contact and heated in a neutral or reducing atmosphere to about 500°C which permits sufficient diffusion of the gold to form an alloy with each surface thus providing a strong vacuum-tight bond. The ability of gold to bond to itself under pressure, even at room temperature, is also used in vacuum tube construction. In one application, a nickel or steel exhaust tube is internally plated with gold approximately 0.25 mm thick and compressed between cylindrical anvils to form a vacuum-tight seal. The tubing is severed where the compression was greatest. Extensive use is now made of the low melting points of silicon-gold (370°C) and germanium-gold (365°C) eutectics to join silicon or germanium slices used in communications devices and electronic computers. Gold coatings are used to prevent the formation of rust on parts which can cause failures in glass-to-metal vacuum seals; it is usual to interpose a layer of nickel between gold and iron. As transistor structures have decreased in size in recent years, the problem of making the electrical contacts has increased and gold wires drawn as fine as 0.0025 mm in diameter may be used. In micro-electronic components with integrated or hybrid thick film circuits, the individual components are produced by screen printing and firing on ceramic wafers at 700° to 1,000°C, using a preparation containing gold and platinium group metals dispersed with a powdered glaze or frit to achieve the required fine particle size. Gold-gallium alloys are used in the high purity form to make alloy junctions in silicon and germanium semi-conductor devices.

The rapid rise in the operating frequency of communications systems and the trend towards miniaturisation of equipment has raised the problem of heat dissipation, which is best solved by using an electrical insulator with a high thermal conductivity. Beryllia possesses the required properties and Consolidated Beryllium (a joint subsidiary of Rio Tinto-Zinc Corporation Limited and Kawecki Berylco Industries Inc of Reading, Penn.,) has developed a process for the deposition of gold on beryllia parts at their Milford Haven laboratory by the sputtering technique of ion bombardment.

Aerospace

The aircraft industry uses relatively large quantities of an alloy containing about 82.5 per cent gold and 17.5 per cent nickel, in the form of heat-resistant brazing alloys. Alloys with less than 65 per cent gold cannot be used as they have relatively inferior joint filling properties, due to their wide melting ranges and high viscosity. Orobraze 980 made by Johnson Matthey Metals Limited, is a gold-copper-nickel-chromium-boron alloy with an effective melting point ranging from 950 to 980°C used by Rolls Royce Limited in the production of RB 211 turbofan aero engines for the Lockheed L1011 Tristar aircraft. It is normally used for fluxless brazing in vacuum or in a protective atmosphere. It has excellent joint filling properties and flow characteristics, coupled with good resistance to oxidation, the joints are smooth and do not require dressing and it has a high strength at elevated temperatures. Gold alloys were used for high-frequency induction brazing, under argon cover of stainless steel tubes in the Apollo Lunar Landing Module: over 1,000 joints were made in tubes ranging from 4.8 to 50 mm in diameter with wall thicknesses of 0.4 to 1.4 mm. This method avoided the use of fluxes whose residues cannot be readily removed from the inside surface of the tubes; the joints were resistant to vibration and withstood internal pressures of up to 211 kg per sq cm. The brazing alloy used was a gold-nickel alloy containing 82 per cent gold and 18 per cent nickel, supplied as precision preformed rings by Engelhard Minerals and Chemicals Corporation of Edison, New Jersey, USA. This alloy was used because it was metallurgically compatible with stainless steel, that is there were no undesirable reactions between the two materials during brazing, and because it contains no constituents which could form refractory oxides.

The very high reflectivity of gold, extending well into the infra-red range, is surpassed only by freshly polished silver. Gold remains untarnished by any atmospheric or corrosive attack, but silver readily tarnishes. Thus, in practice, gold even in the form of a thin film or coating, is the most efficient reflector for infra-red radiation. Gold is a very low emitter of radiation, a surface with a reflectivity of well over 95 per cent in the infra-red region having an emissivity of only 0.05 over a fairly wide range of temperatures compared with stainless steel which at high temperatures has an emissivity of about 0.80 and will therefore radiate much more heat. For heat shields for jet engines, gold is applied to metal surfaces as a preparation known as 'liquid bright gold', which consists essentially of a complex sulphur compound of gold in an organic solvent, together with small additions of readily oxidisable metals such as bismuth or vanadium to ensure gold bonding. This is sprayed on aircraft engines, to ensure uniform coverage, and fired as soon as possible to avoid contamination. A durable film of gold can be readily produced 0.00013 mm in thickness and of negligible weight which will resist attack by jet fuel, hydraulic fluid or engine oil provided that that substrate metal is itself unimpaired, and it will not break down at temperatures up to 750°C.

Similar liquid bright gold coatings are used on drag-chute containers, tail cone assemblies and missile blast shields. Nylon covered with pure gold was used in the Gemini spacecraft as a protective shroud against high energy cosmic radiation for the propulsion, radio and guidance systems. The silicon solar cells that provide power for space vehicles and unmanned satellites use gold current collectors on their front faces and gold areas on their back faces to which electrical contact is made. Gold is used because of its high electrical conductivity, excellent resistance to corrosion and good solderability. Gold-palladium base thermocouples are used in jet aircraft engines for temperature measurement because of the accuracy of the thermo-electric response and their resistance to corrosion and vibration damage.

Building and transport

The gilding of roofs and spires of large buildings, particularly places of assembly or worship, goes back to pre-Christian times and still continues. For example, the domes of some of the Russian Orthodox churches in Moscow have recently been regilded, the large new Hindu temple at the holy city of Benares has a high gilded bronze roof and the Dome of the Rock at Jerusalem, one of the most sacred of Moslem shrines, was repaired in 1961 by the installation of a new dome of gold-plated aluminium. The purpose is partly to emphasise the sense of awe attached to particular buildings, partly to preserve the roof structure and partly to keep the interior cool by reflecting infra-red heat.

Sun insulating glass windows are being used increasingly in new office buildings, particularly those that are clad largely in glass, and also in air-conditioned trains. An extremely thin gold film (about 0.02 microns) is applied to the glass, usually to the inner surface, so that it is protected from mechanical damage. Such films reflect part of the infra-red radiation, keeping the temperature down in summer and reducing heat losses in winter. From the inside, these sun-insulating windows are very light green, but from outside they appear golden yellow. Plate glass with gold films, giving off blue, gold or bronze when viewed from the outside are now commercially available. One type of film used transmits 40 per cent of the visible light, but only 26 per cent of the solar energy enters the building. Where more than 40 per cent light transmission is required a single gold film is not effective because below a critical thickness, gold film ceases to reflect selectively. In an improved type of sun-insulating window, thin dielectric films with a suitable refractive index and thickness are applied to the glass to which a thin gold film is applied by vacuum evaporation. These films are slightly yellowish in transmitted light and have a highly reflective blue appearance from the outside. Where sharper discrimination against infra-red is required, without excessive absorption of visible light, interference filters, using two gold films separated by a filter of magnesium fluoride are used. Very thin films of vacuum deposited gold with an intermediate layer of bismuth oxide, give windows of high optical transparency which are capable of being heated electrically without the diffraction effects which occur when fine wire elements are used. They are pale straw coloured, and absorb about 5 to 8 per cent of the incident light and can carry up to 1,000 watts per sq ft. This type of heated window is used in aircraft, hovercraft, railway locomotives (they are supplied to British Rail), bridge windows of arctic vessels, cameras, microscopes and humidity chambers to provide clear vision combined with de-icing and de-misting facilities.

Dental and medical

Gold is used in dentistry both pure and as a major constituent of alloys with base metals and platinum-group metals used principally for casting, but also as wrought wire solder. Pure gold, because of its high corrosion and tarnish resistance, is used in crowns, for gold inlays, bridges and partial dentures. Wrought gold alloys in wire form are used principally in fabricating orthodontic appliances. Gold solders are used for joining sections of a unit such as an orthodontic appliance, or in a bridge, and for locally building up inlays and crowns. Small quantities of gold are used medically. The use of gold compounds in the treatment of rheumatoid arthritis began experimentally in 1927 and intra-muscular injections usually of about 50 mg of gold compound, containing about 25 mg of gold, at weekly intervals is now an accepted form of treatment. Radioactive gold is also used in the treatment of several forms of cancer, as an injection of a colloidal suspension, as silver-coated particles (to treat lung cancer) and as platinum sheathed seeds.

Other uses

Although one of the densest of metals, extremely light gold foams (with densities of only 0.4 to 1.0 g/cm^3,) are now produced under the trade name 'Retimet' which are used where the exceptionally high resistance to corrosion of gold is a great advantage, as in the coarse filtration of corrosive liquids.

Gold is used in the machining of sintered ingots of tungsten produced by powder metallurgy which are themselves too porous to machine. The ingot is impregnated with gold or gold-copper alloy and machined normally. The gold is then recovered from the chips and machined parts by volatilisation. Very few thermocouples are useful at very low temperatures (down to 4°K, – 269°C) because their voltage output becomes minute. A silver-gold alloy thermocouple is preferable below 80°K (–193°C) where heat conduction along wires can be important and a gold-cobalt versus silver-gold thermocouple is used between 4°K and 300°K (+27°C). Gold-coated plastic is used in face masks for steel workers and is claimed to reflect 95 per cent of the incident infra-red rays. Gold alloyed with 5 to 10 per cent of platinum (to increase the hardness and reduce the grain size) is the preferred metal for crucibles for handling molten sodium hydroxide. These very corrosion resistant alloys are used in laboratory ware.

Gold pen nibs are normally made from 14 carat gold which is elastic enough to avoid cracking. The nibs are usually tipped with a bead of hard alloy containing osmium and iridium with or without ruthenium; ruthenium is now partly replacing the other two more valuable metals. Gold pens and pencils are frequently of rolled gold plate of about 9 carat quality.

Ancient and traditional uses

Wealth. Gold has been used as a store of wealth since prehistoric time and even in primitive pastoral societies in which wealth was represented mainly by the ownership of animals, gold was worn in the form of bracelets, torcs (collars), lunules, mitrae (stomach guards) and pectorals. By the 8th century BC, traders in such cities of western Asia Minor as Ephesus, were using small irregular bars of electrum as a primitive form of currency. By the 5th century BC, gold in the form of coin was found to be convenient for purposes of trade, particularly in Asia, and affluence was made manifest by the use of gold or gold-plated drinking vessels. Gold or gold-plated idols were set up in temples and votive offerings in the form of gold objects were accepted at temples. Some temples lent money and issued gold coins. With the development of a settled agricultural society, however, the main store of wealth in medieval times was held in land, which could be transferred to others only with the aid of elaborate legal documentation and there were categories of persons (for example Jews) who were not permitted to own land. Wealth held in gold could, in general, be transferred readily and there were no restrictions on categories of ownership, although there were severe restrictions on the export of gold plate and coin (which were frequently evaded by traders).

With the conquest of the Americas by the Spaniards, more gold became available in Europe. Large quantities of gold bullion was prepared by melting down temple ornaments, and some of this bullion was transformed into gold coins, which became more abundant. The need to change gold coins of one country into those of another led to the development of banks. The earliest bankers were goldsmiths; in 17th century London they made loans both to private persons and to the Crown. The Bank of England was founded in 1694 to provide the same service on a larger scale. In the 17th century, transfer of cash between banks and payments for exports were in gold coin. The frequency of naval warfare and the risk of attack by pirates, as well as the inconvenience of using shiploads of gold coin led to the development of international banking facilities, but banks were generally obliged to maintain a stock of gold to cover a proportion of their debts.

Ancient coins. The earliest known coinage made in precious metal was struck in electrum, a natural alloy of about 4 parts gold and 1 part silver. The first regular issue of these coins, known as *staters,* was in Lydia, western Asia Minor, about 640 BC. Pure gold coins were also first issued in Lydia, by Croesus, between 560 and 546 BC, but when Cyrus conquered Lydia in 546 BC he seized the wealth of Croesus and Persians became acquainted with the art of coinage. Darius Hystaspes (521 to 486 BC) was the first Persian monarch to issue coins; the gold coins, *darics*, are roughly oval in shape, having been struck from egg-shaped globules of metal. In the middle of the 4th century BC gold was a regular medium of exchange in Europe. Philip II of Macedonia (359 to 336 BC) issued large quantities of gold coins known as *'phillippeioi'* (*philips*) using gold from recently opened mines in Philippi. The immense quantity of gold taken by Alexander the Great when he destroyed the Persian empire in 330 BC enabled him to issue gold coins in even greater quantities than his father had done: his staters were in widespread use in the

Ancient World and remain the most abundant ancient gold coins. They became the gold currency of Rome after the Roman conquest of Macedonia in the early part of the 2nd century BC, and they were imitated by Gauls and Britons.

The first gold currency in the Roman Republic (269 – 30 BC) appeared in 216 BC as a wartime emergency issue of staters and half-staters produced when stocks of silver were running low. By the end of the first century BC, however, gold was no longer in general circulation and one of the first tasks of Augustus (27 BC – AD 14) was the reform of the currency, putting it on a bi-metallic basis and issuing a new gold coin, the *denarius aureus* ('gold penny'), usually referred to as the aureus. For almost a thousand years, gold predominated in the currencies of Europe, almost to the exclusion of silver. In about AD 312 Constantine I issued a new coin, the *solidus,* of pure gold weighing 24 Graeco-Roman carats, struck at 72 to the pound. All payments to the Imperial treasury had to be in solidi which were melted down on receipt and treated as bullion, which was re-made into coin when required for the payment of salaries. For seven centuries the solidus remained pure and unchanged in weight. It was a symbol of imperial greatness admired and accepted as sound currency throughout the civilised world. It became the ancestor of a large family of European coins, including the soldo and the sol. Its memory was preserved within the British monetary system until 1971 as the abbreviation 's' in £.s.d. which was abolished with decimalisation.

The Byzantine emperor Michael IV (1034 – 1041) first debased the solidus and by 1071 its purity was only 8 carats. When the Arabs conquered Syria at the end of the seventh century AD they took over the solidus as their unit of gold, gave it Arabic lettering and renamed it the *dinar* which formed the basis of the currency of the Muslim world for the next five centuries; the name survives in countries around the Persian Gulf and in Yugoslavia. In the 10th century AD the Fatimids of Egypt issued a gold currency which because of its purity became the great coinage of the Mediterranean and was copied by the Crusaders until the Pope forbade it; but the Normans continued the issue of gold coins of Fatimid type when they ruled Sicily. From the end of the 13th century however, gold was replaced by silver in the Moslem world.

The earliest gold coins, including copies of philips, found in Britain date back to about 100 BC and were most probably minted in Gaul. Cynobelinus and his successors were obliged to pay the Romans an annual tribute in gold coins and he struck gold coins at a mint in his capital, Camulodunum (now Colchester), using gold obtained by trade with Wales. There was also a Roman mint in London. Early Anglo-Saxon coins were generally crude imitations of Roman coins, and only a few were of gold. King Offa of Mercia (AD 757 – 796) however issued a gold dinar, inscribed with *Offa rex,* copied from an Arabic dinar of Calif Al Mansur of Baghdad and a gold penny was struck by Aethelred II (AD 978 – 1016). No more gold coins were minted in England until 1257 when Henry III (1216 – 1272) introduced a gold penny, worth 20 silver pennies, which was unpopular. Another attempt to introduce a gold coinage in 1344 was unsuccessful owing to an incorrect ratio of value established between gold and silver and until the reign of Edward III (1327 – 1377) the English currency was based on silver. In 1344 a gold florin was issued weighing nearly 7 grammes and valued at 6 shillings, followed by a half florin or *leopard* and a quarter florin or *helm.* A *noble* weighing nearly 9 grammes valued at 6 shillings eight pence was also issued but in the currency reform of 1351, which established a gold to silver ratio of 1 : 12, the weight of the noble was reduced to under 7.8 grammes. A mint was opened at Calais for the re-coining of continental gold currency into English money. In Scotland, David II (1329 – 1371) struck a gold noble, but few were issued. In 1412 the standard weight of English gold coins was reduced and they were rarely minted after 1426 due to the small supplies of local gold. In 1465 Edward IV issued a new gold coin, the *ryal* or *rose noble*, weighing nearly 7.8 grammes with a value of 10 shillings, soon followed by a a half- and a quarter-ryal, and the *angel*, weighing nearly 5.2 grammes valued at 6 shillings and eight pence, to replace the noble. In medieval times it was usual for the monarch to demand a percentage of the bullion brought to the mint for coining, as part of the feudal right of seignorage. This charge was on occasion considered excessive and acted as a disincentive to coining in gold in England. Foreign gold coins became more popular than local coin and some were accepted throughout England. These included the *fiarino d'oro*, known in England as the *florin*, first issued in Florence in 1252 and the *ducato d'oro* (the *ducat*) struck in Genoa a few years later.

In 1489, during the reign of Henry VII (1485 – 1509) the first gold *sovereigns* were produced: they were valued at 20 shillings and weighed nearly 15.6 grammes. Henry VIII (1509 – 1547) debased the coinage in 1526, introducing 22 carat gold for coins in place of the 23 carat gold formerly used. New gold coins, the crown valued at 4s 6d, the crown of the *double rose* valued at 5 shillings and the half crown, which weighed 6.2 grammes were introduced. In the latter part of this reign the purity of the gold coinage was further reduced to 20 carats, but the coins struck in the reign of Edward VI (1547-1553) were 22 carat, and under Mary (1553 – 1558) were again 23 carat. Elizabeth I (1558 – 1603) minted coins in two purities of gold; the sovereign, or double noble valued at 30 shillings, was minted in 23 carat gold and the pound valued at 20 shillings was in 22 carat gold. The weight of the gold 20 shilling piece was reduced by James I (1603 – 1625), whose coins claim the kingship Magnae Britanniae (of Great Britain), and the new coin was called the *unite*; a gold 4 shilling piece, the *thistle crown* was also introduced.

During the Civil War (1642 – 1649) Charles I struck gold coins at emergency mints at Shrewsbury, Exeter, Chester and at Oxford where three-pound pieces were struck out of plate requisitioned from the colleges. Charles II (1660 – 1685) issued coins made by a new mill and screw process in 1662 and abolished 'hammered coins', but these were not demonetised until 1773. The unite was abolished and new coins valued at 20 shillings (known as the *guinea*) 100 shillings, 40 shillings and 10 shillings were introduced, some being made from gold imported from Africa. A major change in coinage policy was also introduced: gold coins were issued without profit and the expense of the coinage was met by new duties on imported wines, vinegar, cider and beer. Under William and Mary (1688 – 1694) and William III (1694 – 1702) the guinea rose from 20 shillings to 30 shillings, under Anne (1702 – 1714) it was revalued at 21 shillings and six pence and George I (1714 – 1727) finally fixed the value of the guinea at 21 shillings.

During the Napoleonic wars the issue of guineas ceased and bank notes came into general use, but a gold seven shilling piece was minted to relieve the shortage of smaller money. The last coinage of the guineas, half guineas and seven shilling pieces was in 1813; in 1816 gold coins were made the sole standard measure of value and legal tender (silver coins being made legal tender for up to £2 only). The sovereign, valued at £1, and the half sovereign were first issued in 1817, the coins being smaller and thicker than guineas and half guineas, which remained in use. Half sovereigns of the 1821 coinage were soon suppressed because they were so like the sixpence that the latter was gilt and passed as a half-sovereign. Gold coins minted before 1838 are no longer legal tender.

The goldsmith's art

In the late Stone Age (7000 BC to 3000 BC) gold nuggets occurring in stream beds were cold-hammered into thin plates and used for ornamental purposes. They were subsequently decorated by flat chasing using a hammer and punches. With the discovery of the use of heat in metallurgy in about 3,000 BC, small gold objects were cast. In the Bronze Age (1700 BC to 750 BC) there was extensive and very skilled production of gold jewellery and ornaments in many countries.

Because of its softness, and because golden objects did not tarnish, gold was particularly suitable for the production of ceremonial objects. All the great Empires of the Ancient World had golden objects, mainly for ritual purposes and temple decorations. The Egyptians were the largest producers and consumers of gold in the Ancient World. To an agricultural people the sun is all-important and on earth gold most closely resembled the sun. From the association of kings and priests with the sun god Ra (after about 3400 BC), gold was proclaimed to be a royal prerogative. The king sat on a golden throne, wore a golden headdress with the symbol of the cobra god in wrought gold on his brow, had a golden collar and gold sandals. Egyptian and Sumerian kings were buried with a large proportion of the gold treasures that they had collected during their lifetimes, some of the most exquisite examples of the goldsmith's art ever created: there was 112 kg of gold inside the coffin of Tutankhamen.

Rome in the days of the Republic (509 to 27 BC) had little gold. A law of the 3rd century BC forbade a Roman woman to wear more than half an ounce of gold: only senators and knights were permitted to wear gold rings, and then only on special occasions. There was little scope for the goldsmith in Rome until after the Greek empire had been captured in 147 BC and Spain had been occupied and pacified in 133 BC. Rome developed new gold mines in Spain, the Danube provinces and later in Wales. Gold finger rings and ear-rings set with precious stones were produced. Gold vessels were only permitted to be used by members of the Imperial house from Emperors Tiberius (AD 14 – 37) to Aurelianus (AD 270 – 275). Gold medallions used by Rome to 'buy' peaceful neighbours have been unearthed in Germany, Romania, Yugoslavia and Hungary. The Visigoths were twice bought off by bribes of gold. In the 3rd century AD workshops in Roman Gaul were very active in ornamenting gold objects by carving and in chasing relief designs on solid metal. A distinctive feature of 4th century Roman gold jewellery was pierced work, called *opus interrasile* produced by cutting the metal away with a chisel. This technique was later copied in Byzantine jewellery.

Constantinople, when it was the eastern capital of the Roman Empire, was the chief gold market of the day. The furniture in Justinian's palace was covered with gold, and golden lamps and candelabra hung from the walls. Gold was used extensively in the churches of Byzantium and gold altars, doors, lamps, crosses, chalices, reliquaries and gospel covers were produced. The Byzantine emperors wore gold crowns incorporating a cross and decorated with gems.

Small gold objects, including pendants, tweezers and ear and nose ornaments dating from the Chavin period about 800 BC have been found in Peru. As sun worshippers, like the Ancient Egyptians, the Inca people used gold in their ritual and the Temple of the Sun at Cuzco was famous from AD 1200 for the vast quantity of gold objects that it contained. The emperor of Peru in the 15th century AD wore a gold headdress, sat on a gold stool and gold cups were used in his household until, in the 16th century, the Incas were conquered by the Spaniards. In Mexico, cast gold objects have been found, dated around 600 BC. The Aztecs were also sun worshippers using gold in their rituals and their chiefs had gold badges of office and gold jewellery. After the conquests of Mexico and Peru in the 16th century, large quantities of gold bullion arrived in Spain as a result of the melting down of confiscated gold objects, mainly from temples. A proportion of this gold was transformed into ceremonial objects and adornment used in church services and much was used for plate and ornaments owned by the Crown.

In the British Isles, during the Early Bronze Age (2000 BC), alluvial deposits in Southern Ireland were worked for gold, and Ireland became a major source. Ancient Irish annals contain numerous references to gold. A considerable number of golden ornaments and vessels have been exhumed from bogs and prehistoric structures, particularly from the Bog of Cullen on the borders of the counties of Tipperary and Limerick where, in addition to golden vessels and ornaments, crucibles, ladles and other instruments necessary for working gold have been found. The depth of peat beneath which they were found indicates a period of 2,000 to 3,000 years since the relics were deposited. The Leinster people were formerly called Laighnigh an Oir or Lagenians of the gold, because it was in their county that gold was first discovered in Ireland. The skill and fame of the Irish goldsmiths was widely known, and Irish gold objects have been dug up from peat bogs and graves in many parts of the United Kingdom. The gold was cold hammered into finger-rings, ear-rings, necklaces, bracelets and horse trappings. In the Middle Bronze Age, from about 1200 BC onwards, Irish gold jewellery showed oriental influences and became three dimensional. Small penannular ear-rings of coiled gold wire found in Ireland and Northumberland are similar to types popular in the Eastern Mediterranean.

Other prehistoric gold jewellery is also well known in Great Britain. For example thin gold objects thought to have been button coverings and dated between 1650 and 1400 BC have been found in Wiltshire. Celtic gold dress fasteners of a complicated design from Morah in Cornwall are dated about 800 BC: a Celtic brooch with a small animal design covered with gold granulations was found at Dunbeath in Caithness. A repousse gold cape shaped from a large sheet of gold into a covering for the arms, chest and back, dated about the first millenium BC (late Bronze Age), was unearthed at Mold in Clwyd. Neck ornaments, known as torcs, made from twisted gold, were worn by British chieftains on the day of battle, as an insignia of authority, as a badge of honour, and as a mark of noble descent. Five torcs were found at Ipswich in 1968 and one at Ken Hill, near Snettisham, Norfolk, in 1950 has been dated 50 BC. Gold was mined for several hundred years at Ogofau in South Wales during the Roman occupation of Britain, but little appears to have been available for use in jewellery manufactured in Britain, as a heavy tribute in gold was extracted from British rulers in the unoccupied territory. After the evacuation of the Roman forces, England was subjected to invasions by sea rovers who captured gold from ecclesiastical buildings. In Ireland, untroubled by the Romans, gold jewellery ornamented with animal motifs continued to be produced well into the Christian era, but much was also carried away by Viking raiders.

The earliest surviving examples of the Anglo-Saxon goldsmith's work were discovered in a pagan ship burial mound at Sutton Hoo in Suffolk; they are dated between AD 650 and AD 660. Jewellery found included gold shoulder brooches decorated with scarlet cloisonne enamel and a purse (containing 37 gold coins) with an ivory lid decorated with gold and garnets. During the Dark Ages, the monasteries of St Albans and Ely became the leading centres of clerical goldsmithing in England. English kings from Edward the Confessor onwards have always been crowned with gold but in early Medieval England there was little gold available for use in jewellery; the wearing of gold brooches by knights and their families was prohibited during part of the 14th century.

In Tudor times, more gold became available, partly by capture from Spanish ships. Henry VIII wore elaborate gold collars, gold brooches and ornamented buttons. His state regalia of gold included the crown, a sceptre and orb, and gold plate. Miners were sent from Lorraine to Scotland in 1539 to work the gold mines and were placed under the charge of John Mossman, a goldsmith. Between 1538 and 1542 he made a gold crown weighing 41¼ oz, a gold chain weighing 17 oz and a gold whistle for James V and a 35 oz crown and a belt (using 19½ oz) for his queen.

Gold plate and jewellery were taken abroad by Queen Henrietta, wife of Charles I, between 1642 and 1644 for sale in the Low Countries and France to provide ammunition for the Royalist forces during the Civil War. The Royal regalia, including the gold crown of Edward the Confessor, was melted down on Cromwell's orders in 1649 and English goldsmiths were dispersed. Following religious persecution in France towards the end of the 17th century, Huguenot goldsmiths came to London and in the very early 18th century produced magnificent baroque work; in the Queen Anne period (1702 – 1714) 'plain' but handsome gold objects were produced and in the 1740s rococco styles became fashionable. English 18th century goldsmiths mainly followed the neo-classical style.

Gold watches became available in England by the end of the 17th century. As 17th and 18th century watch movements were very expensive they were protected by a double case, the inner of plain gold, the outer being elaborately chased. When the making of watch cases and movements was industrialised, watchcase designs became simpler. Factories for the mass production of stamped gold articles were started in Birmingham in the 18th century and 1798 the use of 18 carat gold was legalised. From 1817 onwards, objects were made from rolled gold and gold chain was mass produced. The majority of English goldsmiths used 9 carat gold (37.5 per cent pure) after this was legalised in 1854.

Gilding

The use of gold leaf for gilding wood and plaster objects goes back for 5,000 years. The Romans were very skilled in the preparation of gold leaf. According to Pliny, gold was beaten so thin that 750 leaves each 9 cm wide could be produced from 31 grammes of gold. Modern gold leaf, generally a little thinner than that used by the Ancient Egyptians, is used for a variety of decorative purposes including picture frames, shop signs, book edges and ornaments.

Special tools are used, because the leaf adheres to steel; boxwood pincers, rattan cane cutters and Arctic hare's foot brushes are typical. The leaf is picked up with a special brush called 'gilder's tip' which is electrostatically charged, usually by passing it through the hair from time to time. Where applied out of doors, for example in lettering a shop front sign, leaf is lightly stuck to a paper support. For fixing to glass, a very dilute solution of gelatine is applied to a very clean surface, leaf is placed on the moist coating and burnished by light rubbing with cotton wool.

The Romans developed a technique for gilding bronze objects by applying a mixture of gold and mercury and recovering the mercury by volatalisation. The principle of chemical plating is the displacement of gold from a solution by a base metal, a process which works well on copper, copper based alloys, nickel and iron. The thickness applied is limited to about 0.25 micron as deposition virtually stops when the base metal is protected by a gold deposit, but the deposit is claimed to be dense and continuous.

Electroplating usually from gold cyanide solutions, can produce coatings ranging from 0.01 micron to 0.1 mm in thickness. Very thin coatings are intended only to give a coloured finish, but thicker deposits are intended to impart the physical properties of solid gold to the plated article and even in some cases to improve on them. The hardness of pure-gold electroplated deposits is a function of grain-size, finer grains giving harder deposits. The periodic reversal of current during electroplating is reported to result in smoother, harder and denser deposits of gold than normal direct current plating produces. The addition of metals such as nickel also gives harder deposits, and some co-deposition of gold and nickel takes place. The addition of small quantities of a cobalt salt to the plating bath reduces the grain size, without lowering the purity of the gold deposited, and is claimed to increase the hardness by 80 per cent and the wear resistance threefold.

A new technique, known as brush plating has recently been developed for gilding objects too large for immersion in normal electroplating baths (for example, statues). The process produces a harder coating with better adherence than that obtained with gold leaf. The object is cleaned cathodically, nickel plated and made the cathode; the anode is a carbon rod wrapped with absorbent cotton covered with surgical gauze dipped into the plating solution and used like a brush.

Very thin continuous coatings of gold under a millionth of a millimetre (0.001 micron) in thickness are produced under vacuum by cathode sputtering evaporation deposition. Such coatings may be applied to passive backing material for use in the electronics industry, or to window glass sheets up to $10m^2$.

The use of gilded tesseral (tiny glazed cubes used in mozaics) was a distinctive feature of Byzantine ornamentation, sixth century mozaic church interiors in Ravenna being notable surviving examples.

A revival of gilt mozaic decoration in modern style is in the Golden Room of Stockholm City Hall (1923). In the modern process for gilding tesserae, 24 carat gold leaf is applied cold to an almost circular damp glass surface 1.0 mm thick, over which is poured molten glass, which may be coloured. After firing at 1,200°C rapid cooling to 600°C, annealing and gradual cooling, the material is cut into strips measuring 2 x 10 cm which are cut into tesserae of the required size.

Specifications

The British Standards Institution has issued the following specifications:
BS 3315 : 1960 'Watch case finishes in gold-alloys'. Incorporating

amendment PD 4680 issued October 1962. The terms 'rolled gold' and 'gold plated' are defined in terms of a minimum of not less than 9 carats. The requirements for marking the finished articles are specified, together with tests designed to ensure adequate quality, thickness and satisfactory adhesion of the gold covering. BS 4292 : 1968 'Electroplated coatings of gold and gold alloy', covers requirements for basis metal, finish and appearance, sampling and testing of undercoats and for thickness, corrosion resistance, purity, adhesion, hardness and marking for engineering applications, general decorative applications and specialised applications in the jewellery trade. Comprehensive appendices give methods of test for coating thickness, resistance to corrosion, purity, adhesion and hardness.

BS 4425 : 1969 'Dental casting alloy' covers mechanical and chemical properties.
BS 3520 : 1962. 'Dental wrought precious metal alloy wire', which must contain not less than 15 per cent by weight of gold.

The London Gold Market sets the following specifications for gold bars to be accepted as good delivery:
Weight:
  Minimum gold content 350 fine ounces.
  Maximum gold content 430 fine ounces.
The weight of each bar shall be expressed in multiples of 0.25 of an ounce and must turn the scale at the weight indicated.
Fineness: Minimum 995 parts per 1,000 of fine gold.
Marks:
  Serial number.
  Stamp of acceptable melter and assayer.

Price

The price of gold in London from 1344 to 1817, on the basis of £ decimal per fine ounce troy, is given in Table 1.

Table 1 Price of gold in London, 1344-1817

Year	*£ per troy ounce fine*	*Year*	*£ per troy ounce fine*
1344	1.36	1549	3.09
1345	1.20	1605	3.68
1347	1.27	1626	4.05
1412	1.52	1718	4.25
1464	1.90	1817	4.25
1526	2.45		

Gold coins were made the sole standard measure of value and legal tender in the United Kingdom in 1817. (Prior to this the standard measure of value had been silver.) In 1817 gold sovereigns valued at 20 shillings were issued replacing the guineas re-valued at 21 shillings in 1719. The Mint value of both these coins was fixed at a rate corresponding to a price of £4.25 per fine ounce troy. The Bank Charter Act of 1844 required the Bank of England to buy gold and pay its notes in gold at this rate. This remained the position until the outbreak of war in August 1914 when the Gold Standard was suspended but the official London price of gold remained unchanged. (South African producers however were now required to bear the cost of insurance and freight, amounting to approximately 1.25 per cent.) The price of gold in London from 1844 to 1967 is shown, in £ per fine ounce troy and converted to £ per kg fine gold, in Table 2 and Fig. 2a.

Table 2 Price of gold in London, 1844-1967, (a)

Period	*£ sterling, per fine oz troy*	*kg*	*Period*	*£ sterling, per fine oz troy*	*kg*
1844-1918	4.25	137	1938	7.13	229
			1939	7.72	248
1919	4.50	145			
1920	5.65	182	1940-1945 (b)	8.40	270
1921	5.35	172	1945-1949 (c)	8.61	277
1922	4.67	150	1949-1953 (d)	12.40	399
1923	4.51	145			
1924	4.68	150	1954	12.47	401
1925	4.27	137	1955	12.55	403
1926	4.25	137	1956	12.51	402
1927	4.25	137	1957	12.52	403
1928	4.25	137	1958	12.49	402
1929	4.25	137	1959	12.49	402
1930	4.25	137	1960	12.56	404
1931	4.63	149	1961	12.55	403
1932	5.90	190	1962	12.50	402
1933	6.24	201	1963	12.53	403
1934	6.88	221	1964	12.57	404
1935	7.11	229	1965	12.56	404
1936	7.01	225	1966	12.59	405
1937	7.04	226	1967	12.82	412

(a) Bank of England buying rate 1817-1918 and 1940-1953. Average of daily market fixings 1919-1939 and 1954 onward.
(b) Operative up to June 1945.
(c) Operative June 1945 to September 1949.
(d) Operative after September 1949.

In September 1919 the Gold Market was set up with daily meetings for gold price fixings in the offices of NM Rothschild & Sons in the City of London. Under this system the price remained under £6 per ounce until the end of 1932 but was over £7 per ounce from 1935 onwards. These daily price fixings were discontinued in September 1939 and for the next 14½ years there was an official price at which the Bank of England bought gold. This price, fixed in terms of the US dollar price reflected the June 1949 devaluation of sterling. The London Gold Market reopened for daily price fixings in March 1954, with prices quoted in US dollars. Prices remained within a narrow range until the autumn of 1960 but rose to over $40 per ounce late in October 1960. In 1961 the Central Banks Gold Pool, operated by the Bank of England, was formed to stabilize the price at around £35 per fine ounce troy and the Federal Reserve Bank of New York made gold available to the Bank of England for sale on the international market. The

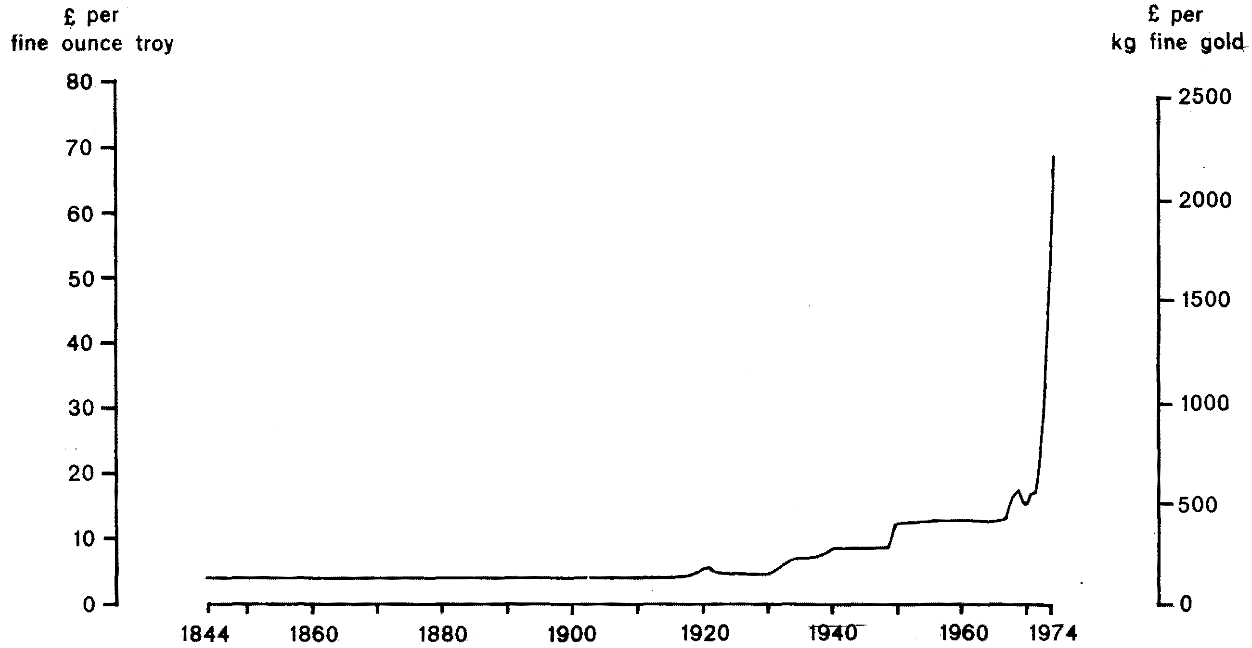

Fig 2a Price of gold in London 1844-1974 (annual averages)

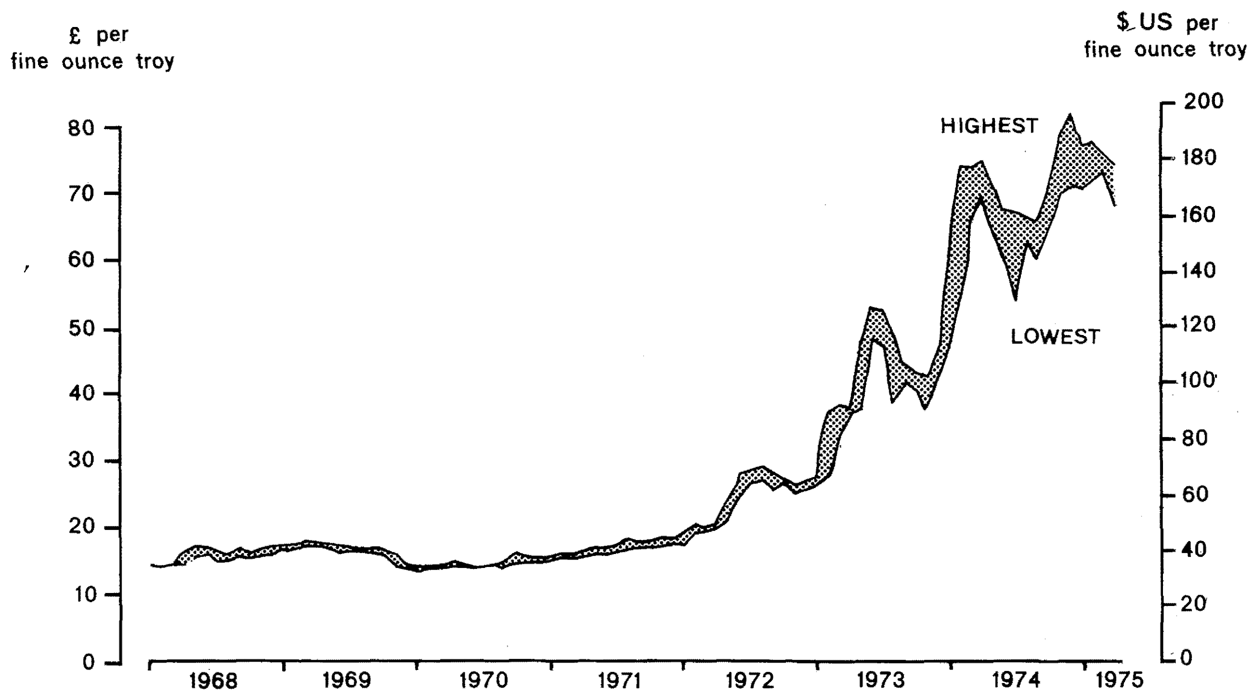

Fig 2b Fluctuations in London gold price,* 1968-1975 (monthly averages)

* London Gold Market price fixings are expressed in $ per fine ounce troy. Values given in £ sterling on this graph are only approximate, being based on $2.40 ≙ £1.

Central Banks Gold Pool limited prices of gold for industrial use to a level close to £35 per fine ounce troy until the further devaluation of sterling in November 1967.

Table 3 Range of London gold price fluctuations, 1968-1975

Year	*Daily fixing in $US per fine ounce troy*			*Equivalent prices in £ sterling, per fine ounce troy*			*kg*
	Lowest	*Highest*	*Average*	*Lowest*	*Highest*	*Average*	*Average*
1968	35.14	42.60	39.26	14.58	17.86	16.41	521
1969	35.00	43.82	41.11	14.60	18.35	17.20	553
1970	34.75	39.19	35.96	14.48	16.40	15.01	483
1971	37.32	43.97	40.81	15.59	18.16	16.73	538
1972	43.72	70.00	58.20	17.12	28.58	23.38	752
1973	63.90	127.00	97.22	27.16	49.32	39.58	1,273
1974	114.75	197.50	158.80	49.60	84.19	67.82	2,180
1975(a)	161.75	186.25	172.66	70.90	76.75	73.09	2,350

(a) January-June

The range of London gold price fluctuations from 1968 to 1975 is shown in table 3 and Fig 2b. In March 1968 there was hectic speculation in gold and on 14 March 1968 the Central Banks Gold Pool ceased to operate and withdrew from the market. On 18 March 1968 Swiss banks formed the Zurich Gold Pool, with quotations in US dollars per fine ounce troy and Swiss francs per kilogramme. As a result of a meeting in Washington a 'Two Tier System' of gold prices came into being with monetary gold pegged at $35 per fine ounce troy and all other gold was allowed to find its own price level.

The London Gold Market reopened for twice daily price fixings at the beginning of April 1968, with prices in US dollars, the sterling equivalent being based on the exchange rate ruling at the moment when the price was fixed. On 30 December 1969 an agreement was reached between the South African Minister of Finance and the managing director of the International Monetary Fund (IMF) whereby South Africa was permitted to sell gold to the International Monetary Fund when two London gold price fixings on any day were $35 per fine ounce troy or below, in effect establishing this as the floor price for a free market. On 8 January 1969 when the gold price at the afternoon's fixing in London fell to $34.95 per fine ounce troy, the IMF came to the rescue by buying the output of new gold from South Africa for the first quarter of 1970. The South African gold mining industry is obliged by law to sell all its production to the South African Government, which sells only part at the commodity price, the remainder being put into reserve. The gold producers are paid at a price governed by the proportion of their production that is sold at the commodity price; gold put into reserve is paid for at the monetary price.

In 1971 the convertibility of the US $ was suspended. The official price (fixed by Congress in 1837 at $20.6718 per fine ounce troy and raised to $35.00 in 1934) was increased to $38.00 in 1972 and $42.22 in 1973. At the official price of $42.22 per fine ounce troy, gold reserves were, in effect, immobilised and to enable gold to be used again for settling international trade balances the West European Central Banks agreed in April 1974, to exchange gold at a price related to the free market level. This has fluctuated between $130 and $198 per fine ounce troy in London during 1974 (reaching $200 in Paris on 30 December). For the first time, gold became more expensive than platinum. Two million ounces of gold were publicly auctioned in New York on 6 January 1975 but bids for only 754,000 ounces were accepted, at prices between $160 and $173.50, the weighted average price being $165.67.

On 9 January 1975 the French government announced that its gold reserves had been revalued at $170.40 an ounce, the average price on the London market two days before. (The 3,140 tonnes of French gold reserves thus appeared in the books of the Bank of France at a value of 75,600 million francs instead of 19,600 million.)

The prices of precious metals in London on 18 July 1975 were quoted as:

Metal	*per gramme*	*per oz troy*
Fine gold	£2.488	£77.385
22 ct gold	£2.430	£75.581
Platinum 95 per cent	£2.498	£77.696
22 ct hallmarked scrap gold	£2.108	£65.57

Technology

Underground Mining

Although some of the underground gold mines which operated on a small scale in Wales, mainly near Dolgellau in Merioneth (Gwynedd), have still not been formally declared abandoned, there has been virtually no mining in the United Kingdom for over 30 years.

Over 70 per cent of the newly mined gold produced in the free world now comes from South Africa, mainly from about 50 large deep mines. The largest and deepest South African gold mine, Western Deep Levels, is expected to have cost over £100 million by 1974 and is estimated to have a life of 60 years, during which time over 100 million tons of payable ore are likely to have been extracted, at the rate of about 10,000 tons of reef and waste a day. The working depth is 3,000 to 3,500 metres where the normal rock temperatures of 47°C to 54°C necessitate the installation of refrigeration equipment which will produce 16,000 tonnes of ice per day. In recent years the gold yield in South Africa has varied between 5 and 30 grammes of gold recovered per tonne of ore milled (uranium may be a co-product). Some mines had been able to operate only as a result of subsidies which the South African government granted to mines with large reserves of low grade ore which could be mined profitably when the price of gold rose, as it did in 1972.

Open pit Mining

Significant amounts of gold are now produced, mainly as by-products or co-products of copper, from very large open pit mines, some of which produce as much as some underground mines in South Africa. For example, the copper mine at Panguna on Bougainville Island, Papua New Guinea, produced about 20 tonnes of gold in 1973. Most of the gold produced in the Philippine Republic (18 tonnes in 1973) came from four open pit mines. A large new open pit near Pueblo Viejo, Dominican Republic, is expected to produce over 10 tonnes of gold a year from ore containing 4 grammes of gold and 35 grammes of silver per tonne. In the event of open pit base metal mining starting in the United Kingdom, some by-product gold could be expected.

Alluvial Mining

Alluvial gold generally occurs in gravels, and is usually concentrated in a 'pay streak' close to the hard rock surface. There may, however, be one or more 'false bottoms' caused by cementation of an alluvial layer. An irregular rock surface is more effective than a smooth one in trapping gold, as it accumulates behind the natural 'riffles' formed by the projections. The gold deposits may now be above, near or considerably below the present normal river levels and there may be a thick overburden of younger, barren deposits. Traditionally the grade is expressed in pennyweights (dwt) per long ton (1 oz troy = 20 dwt = 480 grains = 31.1035 grammes). A grade of ten pennyweights per long ton represents a gold content of 15.3 grammes per tonne. Until about a hundred years ago, most of the world's gold was obtained from alluvial deposits, but since about 1940 they have produced only a minor part. In the Soviet Union however, gold is produced from alluvial deposits on quite a large scale. About 177 tonnes, out of the total production in 1970 of 336 tonnes may have been produced from alluvial deposits. There was little or no development of new placer gold deposits while the price of gold remained at $35 per fine ounce troy, but interest has revived since the recent major increase in price.

In the past, alluvial gold has been mined by very primitive methods on a small scale and at irregular intervals in the Mawddach valley northwest of Dolgellau, North Wales, in the Helmsdale and Blackwater valleys of south-east Sutherland, in the Leadhills area of the Southern Uplands of Scotland, in Devon and in Cornwall. There have been occasional gold rushes, for example in Sutherland about a hundred years ago. The earliest gold miners prospected and worked streams using large domestic cooking pans, hence 'panning', separating the lighter material from the heavier gold and pebbles by swirling and swilling. Special pans are now used for prospecting. The normal method of mining alluvial gold deposits is by dredging but although gold dredgers were once made in the United Kingdom for export, none have been used in the United Kingdom. Electrically operated gold dredges are still used in the Soviet Union. In parts of the USA in recent years gold has been produced profitably as a by-product of sand and gravel workings: there are areas of Scotland where similar circumstances might arise.

Processing

The very high specific gravity of gold (varying from 15.5 to 19.3 according to the amounts of other metals alloyed with it), the readiness with which it forms an amalgam with mercury, and its solubility under favourable conditions in dilute aqueous solutions of alkaline cyanides, are properties utilised in the treatment of ores.

Reduction of ore to the size appropriate for its subsequent treatment is one of the heaviest items in the total cost of treatment and the efficiency with which this is done has a strong influence on the recovery achieved. Small mines use a stamp battery which can break 4 inch pieces of ore to 40 mesh or finer. A number of these were once in operation in the Dolgellau district, worked by water power. The original mill of the St David's Gold and Copper

Company, on the river Hirgwm about 1.5 km south of the mines, had a ten stamp battery fed by ore crushed in a stonebreaker, all driven from a waterwheel. Any gold or amalgam which escaped from the plates of the stamp battery was caught on rocking tables lined with blankets. The blanket process is basically the same as that used in the days of Jason whose 'Golden Fleece' represented the sheepskins used by miners of that day to catch gold. Gwynfynydd mine had a 40 stamp battery regarded at the end of the 19th century as the best of its kind anywhere.

Ores may be dry-ground (as was done at Carn Dochan, near Bala) when they had to be roasted or dehydrated before cyanide treatment; soft decomposed rock requires only coarse grinding. In many deposits, much of the gold is so intimately associated with the sulphide minerals that it can only be extracted by cyanide solutions, despite the health hazard if the process is not controlled rigorously. Modern treatment consists of crushing, milling and recovery by cyanidation, amalgamation, gravity concentration and smelting, or by a combination of these processes. Recovery is high, sometimes exceeding 95 per cent. For example at the Homestake Mining Company's plant, the largest gold mining operation in the USA, approximately 70 per cent of the gold is recovered by amalgamation and 27 per cent by cyanidation. The crushed ore from the gyratory crushers is reduced to about 70 per cent through 0.200 mesh by two stage grinding, using rod mills in open circuit and ball mills in closed circuit with rake classifiers. One grinding circuit uses a ball mill and cyclones. The pulp from the ball mills passes over amalgamators which recover the major part of the gold in the form of amalgam. The overflow from the rake classifiers is separated into sands and slimes in bowl classifiers and treated by cyanidation in separate leaching plants. Sand leaching in vats by gravity percolation recovers about 18 per cent and slime leaching under pressure in filter presses recovers about 9 per cent of the gold produced. The gold in the cyanide solutions is recovered in the precipitation units by adding zinc dust, and the resulting precipitate is smelted to produce crude bullion. The amalgam is heated in retort furnaces, the gold remaining as a residue after the mercury is distilled off and recovered for re-use.

Secondary Recovery

Secondary refined gold is an important part of the gold supply. Gold scrap includes clippings, filings, polishings, scrap jewellery, contaminated solutions, relay contact assemblies, chemical ware, brazing alloys, dental alloys and plated wire. Up to about 1940 more than 80 per cent of the gold scrap originated in the arts field, the remaining 20 per cent being mainly from aircraft industry. Now more than 80 per cent of the gold scrap and waste shipped to secondary refineries is generated industrially. A survey by the US Bureau of Mines showed that the gold content of scrap electronic and electrical parts of military origin commonly varies from 30 to 150 grammes of gold per tonne.

Refining

Gold has been refined in or near London for many centuries. Early metallurgists had little difficulty in recovering gold from base metal ores relying mainly on melting under oxidising conditions (cupellation) to slag off the base metals. Roman gold coins minted in the period of Nero have assayed better than 99 per cent pure. The presence of lead was helpful and if not already present was added either as the metal or the oxide. The separation of gold from silver was difficult for early metallurgists. An unsatisfactory partial separation was obtained by adding sulphur to the salt, which converted the silver to the sulphide without reacting with the gold. This method was replaced by melting antimony sulphide with the gold, the antimony-gold alloy being subsequently heated to remove the antimony.

Most of the world's gold is now refined in South Africa where the world's largest gold refinery is located. Very little ore has been imported into the United Kingdom in recent years but unrefined bullion and gold-bearing waste, scrap, sweepings and residues are regularly imported. Crude bullion is melted and treated by chlorination in the Miller process, or by electrolysis in the Wohwill process. The average purity of gold refined by these processes is 99.6 to 99.7 per cent and 99.99 per cent respectively. As the Wohwill process is slower it is only used for preparing specially pure gold. South African gold is usually 99.6 per cent pure but all Soviet gold is reported to be refined electrolytically to 99.99 per cent pure.

Fabrication

Pure gold may be melted in gas, oil, coke, electrical resistance or high frequency furnaces. It does not react with any of the common refractories under oxidising conditions and does not dissolve hydrogen, oxygen or furnace gases. Clay-graphite crucibles are quite suitable for melting pure gold and most gold alloys. Pure gold presents no metallurgical problems in mechanical working or forming at any temperature below its melting point. Although it work hardens, annealing is unnecessary due to its outstanding malleability.

The unique ductility of gold makes it possible to produce gold leaf 0.1 micron in thickness, which will resist atmospheric attack and oxidation. Sheets of gold sandwiched between layers of parchment are beaten with closely spaced blows of a slightly rounded hammer. The final stage is hammering between 'gold beaters' skins', prepared from ox intestines, coated with special non-metallic powders to prevent sticking and provide the desired friction. The moisture content of the skins is adjusted to provide the optimum mechanical properties. The gold normally used is 96 per cent pure, with about 4 per cent silver, but cheaper gold leaf, unsuitable for outdoor use, is made from an alloy containing more silver. The beating is now usually done by machine. Germany is a major producer of gold leaf and there is substantial production in the United Kingdom, USA, France, Italy and Japan.

Pure gold can be oxy-acetylene welded without difficulty, using pure gold as a filler rod; no flux is required. Electric resistance welding can also be used satisfactorily.

Coatings of gold can be plated on base metals from solution by chemical or electrochemical methods.

Methods of analysis for gold

A wide range of physical and chemical methods is available for the determination of gold and a great deal has been published in recent years on the special problems that still exist. Of the non-destructive methods, the oldest, the measurement of density, is applied particularly to ancient metal objects such as gold coins. This method also has some application in the factory control of the gold clad components of watch cases. The fire assay method of gold analysis was probably first practised by the Romans in the 2nd century BC but it was elaborated in the 16th century particularly by the

Germans. It is very accurate, rapid and particularly suitable for multiple and routine analysis of gold ores and is therefore used in government offices. The weighed sample, wrapped in pure lead foil, is subjected to cupellation in a muffle furnace, the lead is oxidised and removed and the resulting button of precious metal is weighed. Silver and metals of the platinum group remain in the gold and are subsequently separated. The separation of silver from gold, known as 'parting', was once effected by boiling with nitric acid in glass parting flasks, the silver being dissolved, but platinum cups are now used.

Neutron activation analysis techniques are frequently applied in the determination of submicrogramme amounts of constituents. In addition to high sensitivity, they have the advantage that errors arising from contamination during sample preparation are minimised. The results are usually within about 3 per cent for samples weighing between 0.05 and 5.0 microgrammes. Neutron activation analysis is also being used by the IGS in the Mineral Reconnaissance Programme being carried out for the Department of Industry, where the ability to analyse large samples (up to 500 g of material) non-destructively is of great value. An atomic-absorption spectrometric method has been developed by the US Geological Survey for use in the study of the gold content of placer deposits and trace amounts of gold in rocks and plants. The lower limit of detection is 0.005 part per million in the sample. About 25 determinations can be made per man-day by this method which is cheaper than, but not a replacement for, the standard fire assay. Emission spectrography is well suited to the determination of small amounts of most impurities in gold. The mass spectrometer, using gases extracted by vacuum fusion, is effective for sulphur and traces of gas. Solid sample mass spectrometry offers an even more sensitive method of determining impurities than the emission spectrograph. X-ray fluorescence methods have been developed for the determination of gold in solution and in silver beads in both microgramme and milligramme amounts, even in the presence of platinum and palladium, as an alternative to spectrographic and colorometric methods. The X-ray fluorescence is used also for estimating the thickness of gold electrodeposits and for controlling the concentration of gold in electroplating baths.

Wet chemical methods of gold analysis are used to obtain gold values where fire assay equipment is not available. They are mostly based on weighing the gold precipitated by reduction from salts in solution. Great care has to be taken to recover all the gold particles which have a strong tendency to adhere tenaciously to the side of the apparatus. A number of reagents may be used to precipitate the gold, including oxalic acid, sulphur dioxide, hydroquinone and sodium nitrite, the choice depending on the amount of gold and other elements present. A large number of organic reagents, notably citarin, thiophenol and dimethylglyoxime are also available, most of which necessitate ignition before weighing. Tellurium co-precipitation is useful for separating gold from other elements and, particularly, for recovering gold from solutions containing very low concentrations of the metal.

Several titrometric methods, including potentiometric titration, have been developed for the determination of gold in quantities greater than 0.1 mg, but they are less important than gravimetric methods. For example hydroquinone titration can be used for cyanide solutions containing more than 0.0002 per cent of gold. Potassium iodide, ascorbic acid, titanous chloride and dithizone are also used.

Colorimetric methods are frequently used for the determination of micro amounts of gold. They require the measurement of the intensity of absorption at a specific wavelength, and comparison with a standard curve prepared from samples of known concentration Stannous chloride has been used to provide a rapid colorimetric determination of gold by the 'purple of Cassius' test; stannous bromide, bromoaurate, tetraphenyl arsonium chloride, p-diethylamino benzylidene rhodamine and rhodamine B are also used according to the circumstances.

Production

United Kingdom

There is no record of any gold having been produced in the United Kingdom since 1939. Regular returns of United Kingdom gold production date from 1861 when Robert Hunt remarked in the introduction to his *Mineral Statistics of the United Kingdom* 'It is worthy of special note that in 1861 we have an actual return of gold from a British mine'. Since that date the total production of gold from ore mined in the United Kingdom has amounted to nearly four tonnes (Table 4). Gold has also been recovered in the United Kingdom from imported cupreous pyrites and between 1880 and 1920 about 30 to 60 kg were extracted annually, totalling 2,413 kg. From 1912 to 1914, 55.5 kg of gold were extracted from other copper ores and in 1911, 0.12 kg of gold were extracted from arsenical ores.

Statistics relating to refinery output are not available.

Data on production of gold by counties is incomplete, but more than 90 per cent of the total recorded production was obtained from mines in Merioneth (Gwynedd) and most of the remainder from Carmarthenshire (Dyfed), with a small output from Scotland.

Table 4 United Kingdom: Gold production 1860-1939 (by decades)

Years	*Ore mined in tonnes*	*Gold content in kg*
1860-1869	19,000 (a)	516 (b)
1870-1879	140 (a)	85 (b)
1880-1889	11,152 (a)	404 (b)
1890-1899	61,036	834 (b)
1900-1909	180,791	1,733
1910-1919	15,801	149
1920-1929	234	5
1930-1939	21,168	86
Total recorded production	309,322	3,812

(a) Records incomplete
(b) Includes varying amounts of silver

Sources:		
	1860-1881	Mineral Statistics, Memoirs of the Geological Survey.
	1882-1896	Mineral Statistics, Home Office.
	1897-1919	Mines and Quarries; General Report with Statistics; Home Office.
	1920	Mines and Quarries: General Report with Statistics; Mines Department, Board of Trade.
	1921-1938	Annual Reports of the Secretary of Mines; Mines Department, Board of Trade.
	1939	Statistical Digest 1945; Ministry of Fuel and Power.

Table 5 Wales: Gold production 1861-1939 (a)

Year	*Ore in tonnes*	*Gold recovered in kg*
1861	n.a.	89.77
1862	817	164.82
1863	392	17.19
1864	2,374	89.80
1865	4,350	51.77
1866	2,975	23.10
1867	3,293	47.29
1868	1,211	13.55
1869	n.a.	n.a.
1870	n.a.	5.94
1871-3	n.a.	n.a.
1874	n.a.	11.97
1875	n.a.	17.05
1876	n.a.	8.99
1877	n.a.	4.33
1878	n.a.	21.70
1879	n.a.	13.91
1880	n.a.	0.16
1881	n.a.	n.a.
1882	n.a.	7.03
1883	883	2.05
1884	n.a.	n.a.
1885	36	0.11
1886	n.a.	n.a.
1887	1	1.80
1888	3,906	272.00
1889	6,326	120.99
1890	584	6.41
1891	14,344	124.65
1892	10,150	88.18
1893	456	71.82
1894	6,709	131.72
1895	13,479	205.28
1896	2,809	42.07
1897	4,589	63.20
1898	715	12.29
1899	3,096	88.61

Year	*Ore in tonnes*	*Gold recovered in kg*
1900	21,136	415.54
1901	16,637	175.05
1902	30,434	116.23
1903	29,059	154.03
1904	23,575	545.46
1905	16,237	169.51
1906	17,663	47.99
1907	13,186	52.25
1908	7,237	24.26
1909	5,627	32.35
1910	6,253	59.53
1911	2,796	11.01
1912	173	37.32
1913	4	3.83
1914	48	2.46
1915	5,168	28.80
1916	1,359	6.44
1917-9	–	–
1920	1	1.07
1921-7	–	–
1928	163	3.70
1929	71	0.37
1930-1	–	–
1932	n.a.	0.19
1933	137	1.77
1934	509	1.59
1935	804	4.60
1936	6	0.02
1937	800	1.87
1938	18,480	75.52
1939	432	n.a.
Total recorded gold recovery		3,792.31

(a) From 1861 to 1898 gold recovered is recorded as 'bar gold' containing varying amounts of silver, but from 1899 onwards as fine gold.
n.a. = not available

Sources:
1860-1881 Mineral Statistics, Memoirs of the Geological Survey.
1882-1896 Mineral Statistics, Home Office.
1897-1919 Mines and Quarries: General Report with Statistics, Home Office.
1920 Mines and Quarries: General Report with Statistics, Mines Department, Board of Trade.
1921-1938 Annual Reports of the Secretary of Mines, Mines Department, Board of Trade.
1939 Statistical Digest 1945; Ministry of Fuel and Power.

Wales

Production of gold in Wales from 1861-1939 is shown in Table 5 and the production by the major mines is shown in Table 6. The Clogau and Vigra mines (latterly worked together as St David's mine) were the most important, producing 2.5 tonnes from about 170,000 tonnes of ore, an average grade of about 15 grammes per tonne. Gwynfynydd mine produced nearly half a tonne of gold from nearly 55,000 tonnes of ore, an average grade of 8.5 grammes per tonne. These mines contributed about 80 per cent of the total United Kingdom production of gold.

Glasdir mine, 4.8 kms north of Dolgellau, the largest copper producer in the area, produced 55.4 kg of gold during its working life between 1872 and 1914. Carn Dochan mine produced 47 kg of gold from 3,207 tonnes of ore between 1864 and 1866, an average grade of 14.6 grammes per tonne, but between 1895 and 1896, only 6 kg were produced from 1,838 tonnes, an average grade of 3.4 grammes per tonne. Small quantities of gold were produced from Prince Edward mine in the 1860s: the mine was finally abandoned in 1935.

Between 1905 and 1910 the Ogofau mine (Dyfed) produced 4 kg of gold and in 1938, as the Roman Deep mine, it was the largest gold mine in the United Kingdom, with an output of 17,133 tonnes of dressed gold ore containing about 68 kg of fine gold. The mine closed in October 1938 and was abandoned in 1940.

Scotland

Probably about 1 tonne of gold has been produced in Scotland, mostly from the Lowther Hills near Leadhills in the Southern Uplands, which are estimated to have yielded about 0.8 tonne of gold since the Roman era.

Since official statistics were available in 1861, only small quantities of gold have been recorded as produced in Scotland mostly from Sutherland. Official production in Sutherland was recorded as 577 oz (17.9 kg) in 1868 and 17 oz 17 dwt (under 0.6 kg) in 1869, mostly from alluvial deposits near Kildonan. It is probable that officially admitted production on which royalty was paid was substantially less than the amount actually obtained (one source suggests that about five times the amount of gold recorded was in fact produced). Later, in 1896, an attempt was made to reopen digging in the Suisgill Burn, a Helmsdale tributary, but the yield, not returned in official statistics but reported to be only 12 oz 6 dwt (0.4 kg), was uneconomic for over a year's work.

World

The total historical world production of gold is estimated to have been of the order of 100,000 tonnes of which about half has been produced since 1850. Current world production is about 1,500 tonnes a year. The main producing countries are shown in Table 7. South Africa has been the world's largest gold producer for most of the 20th century and a major source of United Kingdom imports of refined bullion. Although output declined to 758 tonnes, South Africa accounted for over 52 per cent of total world output in 1974. There are wide differences in estimates of production of

Table 6 Production from major mines in Wales

CLOGAU AND VIGRA

Year	*Ore in tonnes*	*Gold recovered in kg*
1861	n.a.	89.77
1862	817	164.82
1863	330	16.39
1864	1,706	72.19
1865	1,671	16.55
1866	1,179	6.65
1867	3,293	47.29
1868	1,211	13.55
1869	–	–
1870-3	n.a.	n.a.
1874	n.a.	11.97
1875	n.a.	17.05
	Total recorded	456.23

CLOGAU–ST. DAVID'S

Year	*Ore in tonnes*	*Gold recovered in kg*
1876	n.a.	8.99
1877	n.a.	4.33
1878	n.a.	21.70
1879	n.a.	13.91
1880	n.a.	0.15
1881	–	–
1882	n.a.	7.03
1883	883	1.28
1884-9	n.a.	n.a.
1890	4	0.06
1891	259	16.76
1892	292	40.56
1893	1,012	44.66
1894	1,182	29.75
1895	485	8.30
1896	463	27.87
1897	304	23.20
1898	325	7.50
1899	1,219	88.07
1900	19,775	425.55
1901	15,766	172.24
1902	17,995	94.99
1903	17,403	80.71
1904	14,615	572.83
1905	15,787	172.62
1906	16,412	53.75
1907	13,132	58.69
1908	7,140	26.94
1909	5,471	28.80
1910	6,120	23.05
1911	1,660	4.91
	Total recorded	2,059.20

GWYNFYNYDD

Year	*Ore in tonnes*	*Gold recovered in kg*
1864	5	0.19
1865	1	0.30
1866-1869	n.a.	n.a.
1870	n.a.	5.94
1871	–	–
1872-1882	n.a.	n.a.
1883	50	0.77
1884-1894	n.a.	n.a.
1895	12,193	193.93
1896	1,279	9.70
1897	3,792	30.87
1898	n.a.	n.a.
1899	1,818	11.55
1900	1,321	4.35
1901	738	19.35
1902	12,435	33.56
1903	11,645	89.20
1904	8,961	38.51
1905	2	5.85
1906	714	2.58
	Total recorded	446.65

CARN DOCHAN

Year	*Ore in tonnes*	*Gold recovered in kg*
1864	29	4.39
1865	1,382	26.06
1866	1,796	16.46
1867-1894	nil	nil
1895	802	3.05
1896	1,036	3.11
		Total 53.07

n.a. = not available

Sources: 1860-1881 Mineral Statistics. Memoirs of the Geological Survey.
1882-1896 Mineral Statistics, Home Office.
1897-1911 Mines and Quarries: General Report with Statistics, Home Office.

gold in the USSR but it is clearly the world's second largest producer and sales of Soviet gold are frequently a major contribution to the market. The Philippines is an important supplier of unrefined bullion to United Kingdom.

Table 7 World production of gold by selected countries 1970-74

Tonnes

Producing country	*1970*	*1971*	*1972*	*1973*	*1974*
South Africa	1,000	976	910	855	758
USSR (g)	336	345	360	371	420
Canada	75	69	65	60	52
USA	54	46	45	36	35
Ghana	22	22	23	23	21
Philippines	19	20	19	18	19
Australia	19	21	23	18	16
Rhodesia (g)	15	15	16	16	19
Papua New Guinea	1	1	13	20	20
Japan	8	8	9	10	5
Colombia	6	6	6	7	8
Mexico	6	5	5	5	4
Zaire	5	5	4	3	4
Brazil (g)	5	5	5	4	14
Others *	39	46	47	54	59
Total	1,623	1,594	1,555	1,507	1,454

***Includes Bulgaria, Chile, China, Fiji, India, Indonesia, Nicaragua, North Korea, Peru, Romania, and Yugoslavia.**

Sources: **Institute of Geological Sciences from official sources. (g) Indicates figures derived from *Gold 1975* published by Consolidated Gold Fields Limited.**

Trade

The London Bullion Market was established in 1666, although gold has been an important traded commodity since pre-Roman times. Since 1816 when gold was decreed the sole measure of value in legal tender, London has been the world centre for trade in gold, nearly 80 per cent of the non-communist world's newly mined gold having passed through the vaults of London dealers. The Bank of England operated on the market through its broker until 1961 when the Central Banks Gold Pool was formed, operated by the Bank. In March 1968 this Pool ceased operations as a result of exceptionally heavy speculative demand, and world trade in gold was diverted to the hastily established Zurich Gold Market but the London Gold Market re-opened in its present form in April 1968. Part of the gold traded is not now physically imported into or exported from the United Kingdom, but is traded on the London Gold Market on behalf of the Zurich Gold Market. To encourage the operations of the London Market, foreign nationals are permitted to own bar-gold in the United Kingdom and export it, a facility not now permitted for United Kingdom citizens. There are no such controls on French or (from 31 December 1974) US citizens in respect of the smaller Paris and New York gold markets.

Union Castle boats regularly carried some 1,000 tonnes of gold a year from South Africa to the United Kingdom until 1968, but this fell by over half between 1968 and 1969. In 1969 most of the gold exported from South Africa was flown to Zurich but since 1970 the sea trade has resumed with the United Kingdom although the Bank of England is no longer South Africa's selling agent.

Most gold is imported into the United Kingdom in the form of bars of refined metal and in 1974 over 554 tonnes of refined gold bullion valued at £426 million were imported, compared with nearly 168 tonnes of gold in other forms (Table 8). There has been a substantial net import of gold bullion into the United Kingdom in recent years, except for 1965, 1966 and 1968, but in 1973 and 1974, the net export increased from nearly £180 million to over £1,000 million (Tables 8 and 10). Major sources of imported gold bullion are shown in Table 9, the largest being South Africa, except for 1973 when most was supplied from Saudi Arabia. Gold coinage of legal tender (including Krugerrand) amounted to almost half of the gold imported in forms other than bullion in 1974, over 70 tonnes, valued at £160 million, of which nearly 42 tonnes worth £90 million was from South Africa and 19

Table 8 United Kingdom imports of gold 1970-1974

Trade description	*Unit*	*1970*	*1971*	*1972*	*1973*	*1974(p)*
Refined gold bullion	kg fine gold	914,045	970,304	593,246	669,975	554,583
	£ thousand	429,205	458,522	299,794	422,955	426,279
Unrefined gold bullion	kg	n.a.	n.a.	n.a.	n.a.	9,664
	kg fine gold	33,227	31,074	12,202	11,544	5,766
	£ thousand	15,993	16,548	8,586	14,602	14,159
Unwrought or semi manufactured gold (a)	kg	771	369	2,188	3,548	2,997
	£ thousand	315	173	328	828	1,517
Gold coin of legal tender (b)	kg	1,626	4,120	2,273	3,251	70,374
	£ thousand	824	2,411	1,978	5,525	160,636
Gold coin not of legal tender (c)	kg	1,032	1,329	1,008	4,519	1,286
	£ thousand	653	852	777	5,520	2,423
Gold waste and scrap	kg	n.a.	n.a.	n.a.	n.a.	72,133
	£ thousand	1,149	7,036	5,398	28,768	39,621
Gold leaf	kg	n.a.	n.a.	n.a.	n.a.	670
	£ thousand	52	66	83	118	129
Rolled gold on base metal or silver	kg	n.a.	n.a.	n.a.	n.a.	10,457
	£ thousand	86	120	77	214	459

(a) Except gold bullion and gold leaf, but including platinum plated gold.
(b) Of legal tender in the UK 1970-73. The valuation given is the commodity or market value except for 1974 for which face value is given.
(c) Not of legal tender in the UK 1970-73. The valuation given is the commodity or market value 1970-1974.

(p) provisional

Sources: HM Customs and Excise, Department of Trade.

Table 9 United Kingdom imports of gold bullion by country 1970-1974

Trade description and country	*Unit*	*1970*	*1971*	*1972*	*1973*	*1974(p)*
Refined gold bullion from:						
South Africa	kg fine gold	859,114	912,544	504,132	3	450,343
	£ thousand	402,963	427,481	231,579	4	210,827
Switzerland	kg fine gold	18,115	10,264	16,756	76,342	42,435
	£ thousand	8,512	5,397	13,547	96,633	93,960
France	kg fine gold	21,459	6,324	15,482	39,242	33,530
	£ thousand	10,326	3,380	12,663	48,557	72,838
German Democratic Republic	kg fine gold	8,804	26,260	24,323	218	246
	£ thousand	4,253	14,361	14,828	310	539
Saudi Arabia	kg fine gold	–	–	–	529,160	1,451
	£ thousand	–	–	–	247,719	3,467
Other countries	kg fine gold	6,513	14,912	32,553	25,010	26,578
	£ thousand	3,151	7,903	27,177	29,732	44,648
Total	kg fine gold	914,045	970,304	593,246	669,975	554,583
	£ thousand	429,205	458,522	299,794	422,955	426,279
Unrefined gold bullion from:						
Ghana	kg fine gold	21,936	20,369	3,535	–	–
	£ thousand	10,572	10,902	2,090	–	–
Philippines	kg fine gold	8,064	8,362	6,964	6,321	5,237
	£ thousand	3,905	4,501	5,109	8,031	11,131
Other countries	kg fine gold	3,227	2,343	1,703	5,223	529
	£ thousand	1,516	1,145	1,290	6,571	3,028
Total	kg fine gold	33,227	31,074	12,202	11,544	5,766
	£ thousand	15,993	16,548	8,586	14,602	14,159

(p) provisional

Source: HM Customs and Excise

tonnes worth £47 million from Switzerland. The bulk of the remaining imports of gold was of waste and scrap fit for the recovery of metal or for chemical use, totalling 72 tonnes valued at nearly £40 million in 1974.

Over 678 tonnes of refined gold bullion were exported in 1974, valued at £1,458 million, compared with nearly 527 tonnes valued at £620 million in 1973. The bulk of this bullion was exported to Switzerland (Table 11). Of the remaining 42 tonnes of gold exported in other forms in 1974 nearly 32 tonnes was coinage of legal tender valued at £90 million of which 24 tonnes worth £67 million was exported to Switzerland. Exported bullion is mostly in the form of large bars of about 400 oz (12.4 kg) which are of the London Gold Market's 'good delivery' standard, and which bear the stamp of approved melters and assayers of gold. Other forms of bullion, including the 'ten tola' tablet, accounted for £52 million of bullion exports in 1973 (according to the Annual Bullion Review issued by Samuel Montague and Company Limited) or approximately 8 per cent of the total value of bullion exported.

Trade in gold (coin or bullion) by United Kingdom residents is subject to the provisions of the Exchange Control Act, 1947. Except with Treasury permission, no United Kingdom resident, other than an authorised dealer, may buy, borrow, lend or sell gold. Authorised dealers are listed in The Exchange Control (Authorised Dealers and Depositaries) Order, 1973.

Table 10 United Kingdom exports of gold 1970-1974

Trade description	*Unit*	*1970*	*1971*	*1972*	*1973*	*1974(p)*
Refined gold bullion	kg fine gold	565,249	623,353	457,396	527,219	678,339
	£ thousand	269,933	332,930	306,439	620,389	1,458,131
Unrefined gold bullion	kg	–	–	–	n.a.	9
	kg fine gold	–	–	–	7	8
	£ thousand	–	–	–	1	6
Unwrought or semi manufactured gold (a)	kg	9,203	7,617	3,010	3,350	4,681
	£ thousand	3,420	3,021	1,596	2,384	2,166
Gold coin of legal tender (b)	kg	27,306	5,542	15,958	30,099	32,980
	£ thousand	12,939	3,257	12,195	43,059	90,124
Gold coin not of legal tender (c)	kg	2,503	2,291	1,048	3,782	2,954
	£ thousand	1,725	1,880	1,057	7,003	6,919
Gold waste and scrap	kg	n.a.	n.a.	n.a.	n.a.	511
	£ thousand	9	0	4	24	988
Gold leaf	kg	n.a.	n.a.	n.a.	n.a.	281
	£ thousand	6	21	43	38	51
Rolled gold on base metal or silver	kg	n.a.	n.a.	n.a.	n.a.	703
	£ thousand	126	140	157	166	78

(a) Except gold bullion and gold leaf, but including platinum plated gold.

(b) Of legal tender in the UK 1970-1973. The valuation given is the commodity or market value except for 1974 for which face value is given.

(c) Not of legal tender in the UK 1970-1973. The valuation given is the commodity or market value 1970-1974.

n.a. not available

(p) provisional.

Sources: HM Customs and Excise, Department of Trade.

Table 11 United Kingdom exports of refined gold bullion by country 1970-1974

Country	*Unit*	*1970*	*1971*	*1972*	*1973*	*1974(p)*
To:						
Switzerland	kg fine gold	67,230	232,866	215,940	303,452	455,832
	£ thousand	31,958	126,912	152,787	377,023	971,595
Dubai etc.	kg fine gold	120,617	73,371	32,178	10,140	1,762
	£ thousand	57,770	38,957	19,921	11,793	3,476
France	kg fine gold	90,303	101,723	62,588	17,412	20,100
	£ thousand	43,806	54,883	38,194	18,848	44,593
Japan	kg fine gold	71,329	63,448	23,919	92,609	30,811
	£ thousand	33,453	30,413	11,221	85,964	67,942
Austria	kg fine gold	979	12,686	32,243	20,475	40,304
	£ thousand	493	6,952	23,085	25,700	90,877
Singapore	kg fine gold	64,702	19,488	4,456	11,392	3,281
	£ thousand	30,666	10,337	3,121	14,025	5,998
Macao	kg fine gold	16,201	27,499	14,893	11,747	–
	£ thousand	7,702	14,929	8,732	13,872	–
Other countries	kg fine gold	133,888	92,272	71,179	59,992	126,249
	£ thousand	64,085	49,547	49,378	73,164	273,650
Total	kg fine gold	565,249	623,353	457,396	527,219	678,339
	£ thousand	269,933	332,930	306,439	620,389	1,458,131

(p) provisional

Source: HM Customs and Excise

comprise The Bank of England, the five members of the London Gold Market and 210 banks. The members of the London Gold Market are:

Johnson Matthey Bankers Limited;
N M Rothschild & Sons Limited;
Sharpe Pixley & Company Limited (a subsidiary of Kleinwort Benson Limited);
S Montague & Company Limited;
Mocatta & Goldsmid Limited (a subsidiary of Standard and Chartered Banking Group Limited).

End use

The use of gold in fabrication in the United Kingdom increased by almost 16 per cent from 1970 to 1973 compared with a decline in Free World use in the same period of 38 per cent, these trends reflecting the use of gold for jewellery. The consumption of gold in electronics in the Free World rose by 38 per cent from 1970 to 1973. Fabrication for jewellery and for other uses is shown in Tables 12 and 13. The hoarding of bar gold in developing countries fell from 87.5 tonnes in 1970 to 49.2 tonnes in 1973. A further 28.3 tonnes were dishoarded in 1974. The fabrication of legal tender gold coins rose sharply in 1974, using 285.1 tonnes of gold (54.1 tonnes in 1973). This now appears to be the main use for gold. Gold jewellery fabrication in 1974 fell in the Free World to 223.1 tonnes, less than a quarter of the 1972 quantity, and the production of gold medals and medallions has now almost ceased. Sovereigns and Krugerrands do not bear value added tax in the United Kingdom or other EEC countries, but gold jewellery is liable to tax. Revised regulations introduced in 1974 permit US citizens to acquire gold coins bearing a date earlier than 1960. This has stimulated the restriking of Austrian and Mexican gold coins for the US market.

Table 12 United Kingdom gold fabrication by end use 1970-1974

Tonnes

End use	*1970*	*1971*	*1972*	*1973*	*1974*
Jewellery (a)	14.7	15.5	18.0	20.3	15.8
Electronics	5.8	4.0	5.0	5.5	4.4
Dentistry	1.0	0.8	0.8	0.7	0.6
Other industrial and decorative uses	3.0	3.1	3.2	3.0	2.3
Official coins	1.6	0.5	0.5	0.7	14.7
TOTAL (a)	26.1	23.9	27.5	30.2	37.8

(a) UK and Irish Republic.
Source: Gold 1975 published by Consolidated Gold Fields Ltd.

Table 13 Free World: gold fabrication by end use 1970-1974

Tonnes

End use	*1970*	*1971*	*1972*	*1973*	*1974*
Jewellery	1,062.6	1,058.7	993.7	490.2	223.1
Electronics	93.6	90.6	110.2	130.4	92.2
Dentistry	63.9	70.0	72.5	74.9	61.7
Other industrial and decorative uses	61.9	68.2	71.2	72.0	54.1
Official coins	45.9	52.3	62.0	54.1	285.1
Medals, medallions, and counterfeit coins	53.6	51.7	41.2	20.8	2.3
TOTAL	1,381.5	1,391.5	1,350.8	842.4	718.5

Source: Gold 1975 Published by Consolidated Gold Fields Ltd.

Substitutes

Gold has long been the most satisfactory means of giving stability to paper currencies, although silver has been used and platinum has been suggested. For private hoarding purposes bars of silver are a substitute for gold and are not subject to the same strict legal controls on private ownership which exist in some countries; they are, however, much bulkier, value for value. Silver and platinum group metals can be used as a substitute for gold in jewellery, dental alloys and in some elctronic applications. For some applications, stainless steel, chromium or nickel alloys can be used to replace gold where resistance to corrosion is the main requirement, but the bulk of the article is inevitably increased.

Industry

There has been no gold mining industry in the United Kingdom since 1939, but English companies have a substantial interest in all aspects of gold mining, refining and secondary recovery overseas. Although there are many gold mining companies in the world, most are controlled by a small number of mining finance houses which provide them with technical services. The most important of these companies or those with United Kingdom connections are:

Anglo American Corporation of South Africa Limited, a South African company administering mining, industrial and property companies valued at R3,400 million (£2,200 million) at the end of 1973. It derived 38 per cent of its income in 1973 from mining 346.1 tonnes of gold in South Africa.

Consolidated Gold Fields Limited, the English parent company of the Gold Fields group of companies, whose assets on 30 June 1974 were valued at £686 million. This company derived 28 per cent of its 1973/1974 revenue from mining nearly 167.3 tonnes of gold in South Africa. The group has substantial interests in base metal mining in many countries, in tin mining in Cornwall and in quarrying construction materials in the United Kingdom.

Rio Tinto – Zinc Corporation Limited, an English holding company with total group assets valued at £1,592.9 million at the end of 1973, has world wide mining interests which include by-product gold from base metal mining.

Union Corporation Limited, a South African company, with investments valued at 31 December 1973 at nearly R423.7 million (£275 million), derived nearly 40 per cent of its 1973 revenue from the mining of nearly 89.5 tonnes of gold, mainly in South Africa. Companies in the group are active in mineral exploration in many countries: one of its subsidiaries is Union Corporation (UK) Limited.

Charter Consolidated Limited, an English mining finance company operating internationally, with assets valued on 31 March 1975 at £302 million. It is closely associated with the Anglo American Corporation group, with which it shares a single technical organisation, and with which it works in partnership in developing mining ventures. Charter Consolidated has holdings in Anglo American Corporation of South Africa Limited, Rio Tinto-Zinc Corporation Limited, Union Corporation Limited and Engelhard Minerals and Chemicals Corporation.

Gold refining is still carried on in the United Kingdom but on a smaller scale than formerly, mainly due to the diversion of ore to new refineries in producing countries. There is an increasingly important secondary gold recovery industry in the United Kingdom. *Johnson Matthey Chemicals Limited,* which operates a refinery at Brimsdown near Enfield, specialises in refining precious metals, the production of high purity chemicals, and also recovers gold from secondary materials. It is wholly owned by *Johnson Matthey & Company Limited* whose total assets at 31 March 1974 were valued at nearly £71.9 million, which also owns *Johnson Matthey Bankers Limited* and *Johnson Matthey Investments Limited* which has major interests in gold refineries in South Africa *(Matthey Rustenburg Refiners (Pty) Limited)* the USA (*Matthey Bishop Inc*), Australia (*Matthey, Garrett Pty*), New Zealand (*Matthey, Garrett (NZ) Limited*), India (*Arora-Matthey Limited*) and Italy (*Metalli Preziosi Spa*).

Engelhard Industries Limited is the United Kingdom subsidiary of *Engelhard Minerals & Chemicals Corporation* of Newark, New Jersey, a major US gold fabricator. The US company has subsidiaries in Australia, Austria, Belgium, Canada, Colombia, Denmark, France, Italy, Japan, Mexico, Sweden and Switzerland, and an associate company in South Africa. *Engelhard Industries Limited* owns the Royal Mint Refinery, which they purchased from *N M Rothschild & Sons* in 1967, and *Sheffield Smelting Co Limited* of Sheffield, an old established firm mainly recovering secondary material. Johnson Matthey and Engelhard Industries (including Sheffield Smelting) are the only companies melting down and assaying gold in the United Kingdom, and their marks are acceptable for good delivery on the London Gold Market.

A small number of large companies fabricate gold in the United Kingdom for many user companies with special requirements. *Johnson Matthey Chemicals Limited* the most important United Kingdom producer of gold chemicals, has a plant for the production of liquid golds at Royston, Herts. *Johnson Matthey Metals Limited* specialise in the mechanical production of gold objects at its plant at Shepherds Bush, London. Carat golds and solders for the jewellery trade are made at plants in Birmingham and Sheffield. This company has two subsidiaries *Johnson & Sons Smelting Works Limited* which is wholly owned and *Mallory Metallurgical Products Limited* of Wembley which is 60 per cent owned. *Blythe Colours Limited* of Cresswell, Staffs, a wholly owned subsidiary of *Johnson Matthey & Company Limited,* specialises in ceramic colours and pigments, including some containing gold. This company has subsidiaries and associated companies (via Johnson Matthey Investments Limited) in the Netherlands, Spain, France and Australia. *Engelhard Industries Limited* are engaged in the mechanical fabrication of gold through their Baker Platinum Division at Chessington, Surrey and their Hanovia Liquid Gold Division at Cinderford, Glos. makes gold chemical products for sophisticated surface applications. Johnson Matthey Metals Limited and Engelhard Industries Limited account for the bulk of the United Kingdom production of gold wire, sheet and tube. *G M Whiley & Company Limited* of Ruislip, is the only company making gold leaf and foil in the United Kingdom. *ITT Components Group Europe,* of Paignton, Devon is a major manufacturer of gold film circuits for the electronics industry and manufactures gold plated repeaters for use in submarine telephone cables. *The Radiochemical Centre,* Amersham produces radioisotopes of gold for use in clinical work, industrial research and control. *The International Gold Corporation* provides information on gold for jewellery manufacturers, a major outlet for fabricated gold.

Much of the gold used in the jewellery trade is supplied by the Jewellery and Allied Trades Division of *Johnson Matthey Metals Limited.* Organisations in

London concerned with gold jewellery manufacture include the *British Jewellers Association* and the *Society of Goldsmiths, Jewellers and Kindred Trades.* The *National Association of Goldsmiths* is the retail jewellers association. *The Worshipful Company of Goldsmiths* assays and hallmarks gold and silverware, tests Royal Mint coinage in the annual Trial of the Pyx, and encourages the goldsmith's craft. The Design and Research Centre for the Gold, Silver and Jewellery Industries (formed in 1946) sponsors work on design in conjunction with the Design Centre and on metallurgy in association with the Goldsmiths Company.

Law

Legislation on gold, covering every aspect of ownership, production sales and use, is extensive and goes back to the ancient world, particularly to the laws of the Roman Empire. In many countries ownership of gold and silver resources is treated differently to the ownership of base metal resources.

The ancient world

The gold mines of Egypt were the property of the Pharaohs who controlled their direction. In Classical Greece the development of mineral resources was encouraged by a liberal mining code, citizens and friendly aliens being permitted to mine gold on payment of a royalty of one twenty-fourth part of the net profits. The operators of the mines were regarded as a separate class, similar to farmers and merchants.

According to Roman law, the ownership proper (*dominium strictum*) of all lands was vested in the State but the beneficial or possessory ownership (*dominium utile*) of the lands might or might not have been vested in the State. This distinction also applied to mines and minerals.

Until the beginning of the first century BC there were two main areas in Italy, the immediate area of the Roman state (*ager Romanus*) and the territories of allies (*socii*). During the Republic, land in *ager Romanus* belonged to the governing families (and eventually vested in individuals) both in ownership proper and in beneficial ownership. With the expansion of Roman dominion over Italy, land yielded to Rome became *ager publicus.* Part of this was leased out, part was auctioned off to citizens and part was occupied without title but under the State's tacit toleration. As a consequence of the extensive state ownership of many of the most important mines in the Roman Empire, the underlying theory became accepted that the state held a primary control over all mineral resources. Only Roman citizens could, in general, acquire the right to lease mines for operation.

Prior to their conquest by the Romans, the gold and silver mines in some countries (for example Spain and Macedonia) has belonged exclusively to the State, in both proper and beneficial ownership, and the miners were in the state's direct employ. The Roman Empire adopted the prevailing custom and therefore succeeded to the mineral rights (that is to the ownership of the mines of gold and silver) as well as the more general authority over all other mines. This distinct and peculiar ownership of the mines of precious metal was extended and perpetuated over every province of the empire.

By a decree of the Emperor Gratian (AD 367 to 383) the imperial mining rights were defined as: 'An exclusive right in the Crown to the full legal and beneficial ownership of all gold and silver mines' and a right was vested in the Crown to receive a proportion of the produce of all other mines, called the *Canon Metallicus*; usually this was a tenth of the produce, payable by the actual mine-worker to the Crown directly. If the miner also owned the land he was the owner of the minerals subject only to such payment. If the miner did not own the land he was required to pay a further tenth part of the produce to the owner of the land: subject to the payment of these two tenth parts, the miner owned the minerals. This definition became the expression of Roman imperial or seigneurial rights in respect of mines, by which the beneficial ownership or tenure of land was the right to explore and open new mines conditional only upon payment of royalties to the ruler.

The Institutes and Digest of Justinian in the 6th century AD codified several centuries of precedents and provided the basis for private operation of these mines through the *usufruct,* defined as the right to use another's property and take its fruits, so long as the substance was not impaired. The rights created in the usufructuary with regard to land with mines or quarries was limited to the operation of those mines or quarries; the opening of new mines or quarries was prohibited as a violation of the usufruct. The usufruct system was later abandoned in favour of a system of operation of mines and quarries in the name of the state, by regularly appointed officials, subject to extensive obligations to the state.

United Kingdom

Mineral rights. Since the Roman Conquest, the law in England concerning mines of gold and silver has followed Roman imperial law. The law of England has applied to Wales since 1535 (the position in Scotland is described on p.56). A proprietary title of all mines, as to all lands, was vested in the Crown, in the person of William I and his successors, which by right of conquest or acquest acquired the rights both of ownership and of suzerainty, the mines then being regarded as the exclusive property of the Crown legally as well as beneficially, free from any right or rights of the subject therein. In England gold and silver mines remain the exclusive property of the Crown, by the royal prerogative, and are mines royal. Even if the Crown were to grant lands with all mines in them, royal mines would be excluded. They are not regarded as part of the land in which they are found; *a fortiori* they are not part of the minerals of the land.

The earliest record of a grant of mines of gold and silver in England is in the 27th year of the reign of Edward I (1272-1307) in Devon. Edward III (1327-1377) appointed a Warden of the mines of gold and silver in Devon and Cornwall. In the 28th year of his reign Edward III leased his mines of gold and silver to some Bohemians, in the 32nd year all mines of gold, silver and copper were granted for two years and in the 37th year all mines of gold, silver, lead and tin in Gloucester were granted for 7 years. All persons were allowed to dig for gold and silver in their own lands. During the reign of Philip and Mary (1554-1557) the Earl of Northumberland was granted land and mines within the 'greater waste of Derwentfels' in Cumberland. The area of the grant included a rich copper mine near Keswick at the upper end of the Vale of Newlands, called the Goldscope mine (this mine, which also yielded richly argentiferous galena, pyrite and a little gold, was first mentioned early in the 13th century). The wording of the grant was *'omnes et singulae minerae',* which was interpreted by the Earl to mean that he had been awarded the rights of all the minerals of the area, including gold and silver. In 1563 however, Queen Elizabeth granted mines royal and base metal in eight English counties, including Cumberland, to Houghsetter (also spelt Howster or Hechstetter), a German. When Houghsetter attempted to work the Goldscope mine, the Earl hindered him and an action was brought in the Court of the Exchequer in 1568 between the Queen and the Earl of Northumberland which became famous as 'The Case of Mines'. The Queen's attorney argued that the entire ore belonged to the Queen because she could not get the gold or silver except by melting the copper. The judgement was that if gold or silver was contained in base metal in the land of a subject, not merely the gold or silver, but such base metal also belonged to the Crown by prerogative. On 28 May 1568 the Queen formed two corporations 'The Society for Mines Royal' having the grant and care of gold, silver, copper etc, within eight English counties and all of Wales and 'The Society for Minerals and Battery-works', concerned mainly with metallurgical work. The first reason given for the Queen committing mines to corporations was 'that the Queen's Prerogative therein might be permanent for our Laws say that corporations never die'.

An opinion of counsel given in 1640 – 1641, however, was that if the gold and silver was not contained in the base metal to such an extent as to make it worth the cost of extraction, the base metal belonged to the subject, and as a result the law as expressed in the Case of Mines was relaxed in favour of the subject. To remedy the uncertainty arising from the Case of Mines, two Acts were passed in the reign of William and Mary (1688-1694), to secure to the subject the copper, iron, tin and lead ores found in his land (or the full value thereof as fixed by statute) and at the same time to secure to the Crown all the gold and silver, if it chooses to take it, paying the value of the copper, iron, tin and lead ores which accompany it. The first, in 1688 declared that no mine of tin, copper, iron or lead should thereafter be taken to be a royal mine, although gold or silver might be extracted from it. The second, passed in 1693, provided that:

> 'all owners or proprietors of any mines in England or Wales wherein any ore then was, or thereafter should be discovered or wrought and in which there was copper, tin, iron or lead, should hold and enjoy the same mines notwithstanding that they should be pretended or claimed to be royal mines, – the Crown, nevertheless, and all persons claiming royal mines through the Crown, being given the right to purchase the ore of any such mines (other than tin ore in the counties of Devon and Cornwall) upon payment therefor, within thirty days after the ore was raised, washed and made merchantable, the price for purchase was (1)for ore with copper £16 per ton; (2),for ore in which there was tin, 40s per ton; (3) for ore in which was iron 40s per ton; and (4) for ore in which was lead, £9 per ton; in default of payment the owners were to be at liberty to sell the ore for their own use'.

In 1815 the price for the purchase of ore in which was lead, was raised to £25 per ton. These Acts do not deal with ores of zinc, although zinc blende is often auriferous. The Crown cannot be called upon to exercise its right of pre-emption until the ore has been 'washed, made clean and merchantable'. It is probable that the obligation to 'wash and make clean' is on the subject. The subject cannot sell until the Crown has made default, and the Crown cannot make default until the ore has been washed and made clean.

In 1891 the defendant in the case of the Attorney-General v Morgan was working a mine near Dolgellau in Merioneth (Gwynedd) as a gold mine. He claimed that he was working within the terms of the Act of 1693, as the mine also contained copper, iron and lead. It was held that as these metals occurred in such small quantities as not to be worth working, the mine was in substance a gold mine and that in this case the ancient prerogative of the Crown was not affected by the Acts of William and Mary.

The continued existence of the Scottish legal system was guaranteed in the Acts of Union of 1706 which united the Kingdoms of England and Scotland. An Act of 1567 provided that neither Orkney or Shetland are subject to the common law of Scotland, but retain Udal law, by which landowners have absolute freehold, including over all minerals. All gold mines in Scotland were declared to belong to the King in an Act of the Scottish Parliament of 1424, still valid, which reads

> 'Item gif ony myne of golde or silver be fundyn in ony lordis landis of the realm and it may be prowyt that thre halfpennys of silver may be fynit owt of the punde of leide. The lordis of parliament consentis that sik myne be the kingis as is vsuale in vthir realmys'
>
> ('If any mine of gold or silver be found in the land of any lord of the realm and it may be proved that three silver half pence may be made from a pound of lead, the lords of parliament consent that this mine is the king's as is usual in other realms').

This Act of Annexation was followed by the Mines and Metals Act, 1592 of James VI, which authorised the king to feu mines and minerals, gold and silver being specifically mentioned. This Act was repealed in part only in 1906 and by it the Crown is still bound, when required, to make a grant of precious metals to the proprietor of the lands in which they are found in consideration of a payment of a royalty. The Act may not however apply to the Orkney and Shetland Isles as in 1669 by an 'Act for the annexation of Orkney and Zetland to the Crown'. Charles II re-asserted royal rights over mines of gold, silver, copper and other minerals within the bounds of the 'Earldome of Orkney and the Lordship of Zetland'

In 1760 George III surrendered all hereditary Crown rights and estates in exchange for an annual income (known as the Civil List). The Crown Estate including the '*Mines Royal*', is now managed by the Crown Estate Commissioners, as determined by the Crown Estate Act 1961.

In respect to gold the Crown Estate Commissioners issue:

> PERMITS to prospect for and take away specimens, tenable for one year, in a relatively small area with no right to renew and no mining option. These permits are now seldom granted, and then usually as a preliminary to the grant of a prospecting licence;
>
> PROSPECTING LICENCES to bona fide mineral operators, for periods of from two to five years on payment of a sum which depends upon the area licensed, potential value etc. This licence gives the operator the right to take out a production lease, the heads of terms being specified on the licence;
>
> MINING LEASES for periods, such as 21 years, with options to terminate the lease at regular intervals. The lessee pays a specified annual rent merging into royalty.

Before a permit or licence is granted, the applicant must satisfy the Commissioners that he has the consent of the surface owner to enter the land and, if the Crown does not own other minerals and they are severed from the surface, the consent of the mineral owner is also required. The

Commissioners will issue a lease automatically to a base metal mine which is also producing some gold and silver, charging a royalty of one twenty-fifth of the net value of the gold or silver recovered.

The mineral rights position in Northern Ireland was greatly simplified by the Mineral Development Act (Northern Ireland) 1969 and by the Statute Law Repeals Act 1969, which repealed section 4 of the Royal Mines Act (Ireland) 1705 and the Mines Act (Ireland) 1723. Mines and minerals, including royal minerals, are vested in the Ministry of Commerce, Belfast, which issues permits, licences and leases.

In the Isle of Man the Tynwald Court has administrative and financial control of the island (which is not part of the United Kingdom) and Manx laws differ in some details from those of England.

In 1679 Charles II granted the Earl of Derby all mines royal of gold and silver on the island. The grant lapsed in 1735 with the death of the 10th Earl (whose family had ruled the island since 1405) and the Lordship of Man passed to the second Duke of Atholl in 1736. Under the Isle of Man Purchase Act, 1765, Manx Crown rights were revested in the English Crown, the third Duke receiving £70,000 compensation and all rights to mines and minerals on the island were conveyed to the Crown in 1829 by the fourth Duke for a further payment. The Isle of Man Act, 1958 repealed United Kingdom Acts regulating mines and quarries on the island. Permits, licences and leases relating to minerals are now issued in Douglas by the Forestry, Mines and Lands Board of the Tynwald.

Hallmarking. The marking of gold objects to denote their quality began in Ancient Egypt during the first dynasty when the device of King Menes was applied to 14 gramme tablets. In Roman times gold bars were stamped with the marks of a pro-consul and a mint-master. Early medieval goldsmiths formed guilds to protect and regulate their trade; the London guild was fined in 1180 for having been set up without the King's licence. A code of statutes for regulating goldsmiths in Paris, issued in 1260, required the gold used to be 'of the touch of Paris'. This term for gold of 19⅕ carats was first used in an English statute in 1300, when the standard mark selected was the leopard's head. Wardens were ordered to go from shop to shop among the goldsmiths assaying gold and confiscating, as forfeit to the King, all not of this standard. Goldsmiths outside London were obliged to have their goldware brought to London 'to be ascertained of their Touch. And if any goldsmith be attained that he hath done otherwise, he shall be punished by imprisonment and by ransom at the King's pleasure'.

'The Wardens and Commonalty of the Mystery of Goldsmiths of the City of London' were incorporated by letters patent in 1327. In 1363 every master goldsmith was required to have his own mark, which was to be placed on his work after it had been assayed and stamped with king's mark. The makers marks were usually devices from the goldsmiths' trade signs, such as a jug, a fish or a bow and arrow. The mark of the city or borough of manufacture was also required in 1378 (and penalties of double the value of the object were imposed for selling goldware without a maker's mark).

The standard was reduced to 16 carat in 1401 but raised to 18 carat in 1477, when the standard mark was changed to a leopard's head crowned. In 1576 no goldsmith was allowed to work, sell or exchange any wares of gold less in fineness than 22 carat. The 18 carat standard gold was reintroduced in 1798, marked with a crown and the figure 18. Reduced standards of 15, 12 and 9 carat were allowed in 1854, stamped with the figures but without the crown, but 15 and 12 carat standards were abolished in 1932 when 14 carat standard gold was introduced. From 1844 onward, gold of 22 carat standard was stamped with a crown and the figure 22 (instead of the lion passant used since 1544). Goldware produced since 1478 has also been required to carry a date letter indicating the year of marking, 20 year cycles of letters being used. For centuries London had a monopoly for marking goldware in England, but the assaying of gold in Birmingham was permitted in 1824 and in Sheffield in 1903, both as a result of local Acts.

The Plate Duty Act, 1784 (repealed 1890) required a duty stamp, the sovereign's head, to be impressed at assay offices on manufactured objects of gold. The duty on gold plate began at eight shillings an ounce, but was raised to seventeen shillings an ounce in 1815. The Customs Act, 1842, forbade the sale of imported plate unless it was duly assayed and marked, but it was amended later in the same year to exempt ornamental plate made before 1800. An additional marking, the letter F, was placed on imported plate as a consequence of the Customs Act, 1867, and an Order in Council in 1904 required the carat value and purity in decimals of foreign gold plate to be marked.

In Scotland, hallmarking began with an Act of 1457 'Of the Deacon of Goldsmithes; and of the marking of their warke'. The Deacon was to be 'a cunning man of gude conscience' and he was required to place his mark alongside that of the maker; the standard for gold was 20 carat, raised to 22 carat in 1555. In 1586 James VI granted the Deacon and Master of the Goldsmiths' Craft in Edinburgh their first letters patent, giving them the power to search for gold and silver work and to try whether it was of the fineness required by law, and to seize all that should appear deficient. The Charter of Incorporation of the Goldsmiths of Edinburgh granted by James VII in 1687 extended their powers over the whole of Scotland. In 1759 deacons' marks were abolished and the standard mark of a thistle was substituted; from 1784 to 1890 the Sovereign's head was also added as a duty mark. The Glasgow Goldsmiths' Company was incorporated by statute in 1819, with powers extending for 40 miles around the city. A lion rampant was allotted as their mark, to go alongside the town mark. The Glasgow assay office closed in 1964. An Act of William IV of 1836 limited the power of assay to Edinburgh and Glasgow (prior to this, burghs had the power to make their own arrangement and prohibited the sale of plate made outside Scotland, unless it was re-assayed and stamped at the Edinburgh or Glasgow offices).

The Hallmarking Act, 1973 made extensive modifications to earlier legislation. The following four offices now grant 'approved hallmarks'.

- The Wardens and Commonalty of the Mystery of Goldsmiths of the City of London.
- The Incorporation of Goldsmiths of the City of Edinburgh.
- The Guardians of the Standard of Wrought Plate in Birmingham.
- The Guardians of the Standard of Wrought Plate within the town of Sheffield.

Hallmarks struck by the Wardens and Commonalty of Goldsmiths of the City of Dublin before 1 April 1923 are also approved, as are the marks of an assay office under the law of a country outside the United Kingdom designated by order of the Secretary of State as marks recognised under an international convention, such marks being referred to in the Act as 'convention hallmarks'. There are two types of approved hallmarks, those for articles made in the United Kingdom and those placed in the United Kingdom on articles made elsewhere. The approved hallmarks are:

Assay office	*Articles made in UK*	*Other articles*
London	A leopard's head	The sign of the constellation of Leo
Edinburgh	A castle	St Andrew's cross
Birmingham	An anchor	An equilateral triangle
Sheffield	A rose	The sign of the constellation of Libra

The standard mark of quality which must be put on gold objects offered for sale in the United Kingdom is the fineness, 375, 585, 750 or 916.6 (corresponding to 9, 14, 18 and 22 carat formerly used). Objects made in the United Kingdom must also bear a crown, in addition to the fineness figures. There are, however, categories of objects exempt from hallmarking such as those intended for medical, dental, veterinary, scientific or industrial purposes, battered articles fit only to be remanufactured, coin, gold thread or raw material (including bar, plate, sheet, foil, rod, wire, strip tube or bullion).

Wedding rings (and salt spoons) are not exempt. No article can be struck with the approved hallmarks unless the assay office is satisfied that there has not been any excessive use of solder, and the solder used must have a fineness of not less than 750 for 916.6 articles, and for white gold of fineness 750 the solder must have a fineness of not less than 500. No hallmarking is required for objects intended for dispatch to a destination outside the United Kingdom, or only in transit.

A British Hallmarking Council was set up on 1 January 1974 to supervise the assay offices and the implementation of the Act. It is an offence to offer for sale in the United Kingdom an object described as gold unless it is properly hallmarked and enforcement is part of the duty of every local weights and measures authority under section 26 of the Trade Descriptions Act, 1968. There are powers to make test purchases, enter premises, inspect, and seize goods and documents.

Twenty-nine other countries use hallmarks on their gold wares, but the marks and some of the standards are different.

Treasure. Those gold objects found on land in England and Wales which are classified as treasure trove are dealt with under section 36 of the Coroners Act, 1887. Objects of gold or silver (including coins, plate and bullion) which have been hidden in the soil or in buildings and of which the original owner cannot be traced, are treasure trove. They are the property of the Crown (unless, as in some rare cases, the 'franchise of treasure trove' has been expressly granted to a subject in so far as finds in the particular locality are concerned). It is important for historical and archaelogical reasons that any such finds should not be concealed, but should be reported and handed over in their entirety to the proper authority (the coroner for the district in which the find is made); a finder who fails to do this may be guilty of a criminal offence. It is the duty of the coroner to summon a jury and hold an inquest in order to inquire whether the articles found are or are not treasure trove and who was the finder or were the finders thereof. If the find is reported promptly and it is decided that it is treasure trove, the finder receives its full market value if it is retained for the Crown, the Queen, the Duke of Cornwall, or for a museum. If it is not retained, he will receive back the objects themselves, with full liberty to do what he likes with them; or, if he wishes it, the British Museum will sell them for him at the best price obtainable. The reward may be divided if the coroner decides that more than one person was concerned in the finding, but it should be emphasised that the reward is made to the actual finder(s) and not to the owner or occupier of the land.

Where odd gold coins are found on the surface of the soil, with no element of hiding, they may belong to the owner of the land. In the case of objects deposited in a grave, or given to the gods, as for instance in the case of the Saxon ship burial discovered at Sutton Hoo in 1939, the treasure belongs to the ground landlord (in this case, it was later donated to the nation).

All finds in Scotland are treasure trove and belong to the Crown, which does not have to establish its title in the courts. All finds must be reported immediately to the Procurator-Fiscal who takes possession: the Museum of Antiquities, Edinburgh values them.

Several ships including galleons belonging to the Spanish armada, carrying gold ornaments and coin have been wrecked around the British Isles. At common law, by virtue of the royal prerogative, and under section 523 of the Merchant Shipping Act, 1894, the Crown is entitled to all unclaimed wrecks found in or on the shores of the sea or any tidal water, where the right has not been granted to any other person. Anyone finding or taking possession of a wreck within the United Kingdom must give notice to the receiver of wreck for the district (appointed by the Secretary of State for the Environment). Under section 528 of the same Act the Department of Trade, with the consent of the Treasury, may purchase for and on behalf of Her Majesty, any rights to wreck possessed by any other person. In order to conserve the historical and archaeological evidence contained in wrecks, the Secretary of State for the Environment may designate the area around the site of a wreck as a restricted area under the Protection of Wrecks Act, 1973. These restrictions apply to any part of the United Kingdom territorial waters and include any part of a river within the ebb and flow of ordinary spring tides. It is an offence (punishable on summary conviction by a fine of £400) to remove any object formerly contained in a wreck, or to carry out any salvage operations directed to the exploration of any wreck, except under licence from the Secretary of State.

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