Farnham Geological Society

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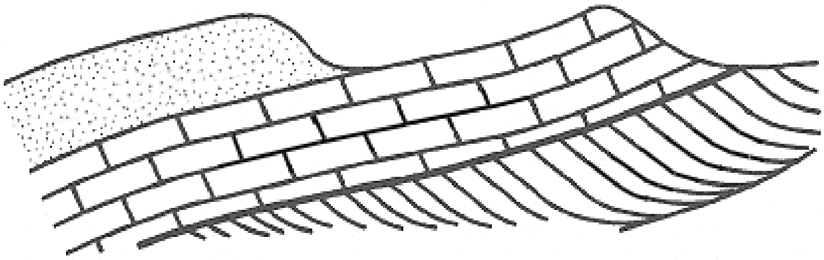

A local group within the GA

Vol. 15 No.1 **Newsletter** February 2012

Issue No: 80

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Editorial

Time flies - we are in 2012 already and it is time for another newsletter. I hope you have all had a good Christmas / New Year break and are ready for a lot of geology to come your way this year. We have a good series of lectures and field trips planned so make sure you participate and enjoy as many of them as you can. There is so much in this Newsletter that I will have to wait until June to report on the other field trips and lectures to date. I have yet to report on Sanjeev Gupta's and Roger Lloyd's talks, but if there are any other talks or field trip reports I have missed, please let me know.

My thanks go to John Stanley who has put together the Index of Past Newsletters which can be accessed from the website: *Newslette/Index of Feature Articles and Field trip Reports*. John has also offered to (been press-ganged into) adding members' photos from FGS field trips onto the photographic website. So please send him all your FGS field trip photos with location, date, description of feature and people, as relevant. It would be a great shame if all Graham's hard work, and your enjoyment of his field trips, were not recorded for posterity.

Liz Aston

FGS Field trip programme - 2012

Saturday May 5th: The Hertfordshire puddingstone mystery - Led by Graham Williams

The Puddingstone lurks in Hertfordshire's fields, where it attacks farmers' ploughs. Puddingstone fragments were treated as Pagan idols, Breeding stones, Growing stones and Hagstones (Witch stones). Where does it hide? How was it formed? When was it formed? Perhaps it really is a Breeding stone growing randomly in the fields. We tour the area around Hertford and Much Hadham to find out more.

Sunday to Sunday June 10th – 16th: Geology of Northern Northumberland - Led by Dr Leslie Dunlop

Wooler provides easy access to the Cheviot Hills and the coast. We will examine the Silurian strata into which the volcanic complex of the Cheviots was emplaced, and look at later Devonian and Lower Carboniferous sediments. The most recent bedrock is the Whin Sill dolerite, seen most dramatically on the coast at Lindisfarne. Two of Hutton's unconformities, which shaped his theories, are at Siccar Point and Jedburgh. Finally, we hope to visit the Farne Islands to see the Whin Sill and the wildlife. We stay at the Tankerville Arms 17thC coaching inn, an independent family run hotel noted for its food.

Thursday July 5th: Betchworth & Reigate, Chalk & Greensand - Led by Dr Graham Williams

We visit a disused Chalk quarry and a working Greensand quarry. The Reigate Greensand quarry shows not only particularly fine exposures of both sedimentary structures but also tectonic structures – unusual in such a friable sediment. Also, we will look at how to examine, describe and interpret rocks.

Friday to Monday, August 31st to September 3rd: The Yorkshire Dales - Led by David Walmsley

Ingleton, Clitheroe, Malham, Salthill are all famous geological locations. We will see the geology of Craven Fault, Lower Palaeozoic sediments of the Askrig Block, the sub Carboniferous unconformity, Carboniferous Limestone reefs and Waulsortian Mud Mounds; also, water sinks and hydrogeology, limestone pavements, clints & grykes, and the relationship between geology and Romano-British and Norman archaeology. We stay in a typical Yorkshire budget hotel in Clapham,

Sunday September 30th: Ivinghoe & Woburn - Led by Dr Graham Williams

The Ivinghoe Beacon walk demonstrates the relationship between rock, Quaternary (glacial and periglacial) processes and landscape; it provides one of the few opportunities to compare the Chalk Rock and the Middle Chalk which form such prominent landscape features. The Woburn Sands are justifiably famous for their shallow marine sedimentary structures including huge sand waves.

Saturday to Sunday October 13th to 14th: Rivers through geological time - GA Conference, Exeter

FGS members can join this conference at the Royal Albert Museum in Exeter. There will be a day of lectures by eminent geologists describing river systems from Pre-Cambrian to Quaternary times, followed by a day of field trips including Triassic, Tertiary and Quaternary fluvial sites. This promises to be a very exciting weekend.

I hope this programme will provide something of interest for everybody - interesting places, beautiful landscapes and seascapes, wild life and plants, ancient and modern rocks, building stones, ancient and 'modern ' archaeology and good food. Please contact me if you wish to join any of the trips.

Dr Graham M Williams FGS Field Trip Secretary

FGS monthly meetings - 2012

Date	Speaker	Title
13 January	Roger Lloyd Member FGS	Geology Of China
10 February	Dr Andrew Coates Mullard Space Laboratory	European Exploration of Mars
16 March	Dr Richard Scrivener Consultant ex BGS	Mineralisation in the rocks of South West England
13 April	Dr Gina Barnes SOAS University of London	Tectonic archaeology in Japan: volcanoes and earthquakes in the archaeological record
11 May	Dr John Potter University of Reading	Introduction to Ecclesiastical Geology
8 June	Dr Lesley Dunlop Northumbria University	Geology of Northumberland
13 July	John Stanley & Edward Finch FGS	tba
14 September	Dr Paul Taylor Natural History Museum	The animals that David Attenborough forgot: the natural history of fossil and living Bryozoa'
12 October	Dr Douglas Robinson Bristol University	Geology of Naxos
9 November	Dr Mick Frogley University of Sussex	Mud, Mites and the Incan Empire: Quaternary palaeoenvironments in the Andean Highlands
14 December	Dr R Moody Consultant	History of Dinosaurs and art

FGS field trip to Isle of Thanet, 1-2 October 2011

Band of nodular flint. Radiolarians, sponge spicules, diatoms and other siliceous plankton provided the silica to form flint in gaps in the chalk left by erosion surfaces, burrows and solution hollows.

Joss Bay near Margate: We stood in glorious sunshine, with our backs to the blue sea and crowded beach to survey the cliff. The base was the upper Seaford Chalk formation. It was deposited, mostly of biogenic material, in the Cretaceous when Kent was underwater at around 450N. In the upper portion of chalk were periglacial features from the Pleistocene. Then fine angular sand, a palaeosol and loess just below the grass. Martin Bates, who was guiding us through the complications of Quaternary geology, pointed out the outline of a Holocene river. It was post ice age high sea levels that made Thanet an island. It remained one until medieval times. Thanet is now mostly dry but many dry valleys mark the path of old water courses. Martin described braided rivers carrying sediment laden melt-water in summer and depositing the fine, angular silt (with some clay) in winter. Wind would then blow the loess covering large areas. The buff coloured, angular grains, with vertical capillaries, form steep faces, identifiable by up-down striations. There was a marked flint band and several nodular flints in the periglacial region. The chalk was fractured, especially towards the top. Martin described the polygonal features and stripes to be found on the cliff tops, another periglacial feature. The chalk chimney was attributed to the warming period at the end of the last ice age, around 10,000 ybp.

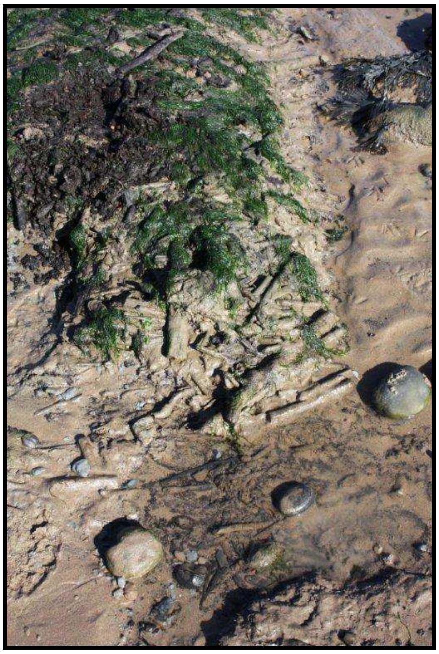
Flare structures in the upper chalk caused by cryoturbation in the Devensian. (Devensian = last stage of the Quaternary, and followed by the Holocene at 10,000 ybp.)

These flint bands provide useful correlation. We were to see the Whitakers at various locations, even from the terrace bar of our hotel.

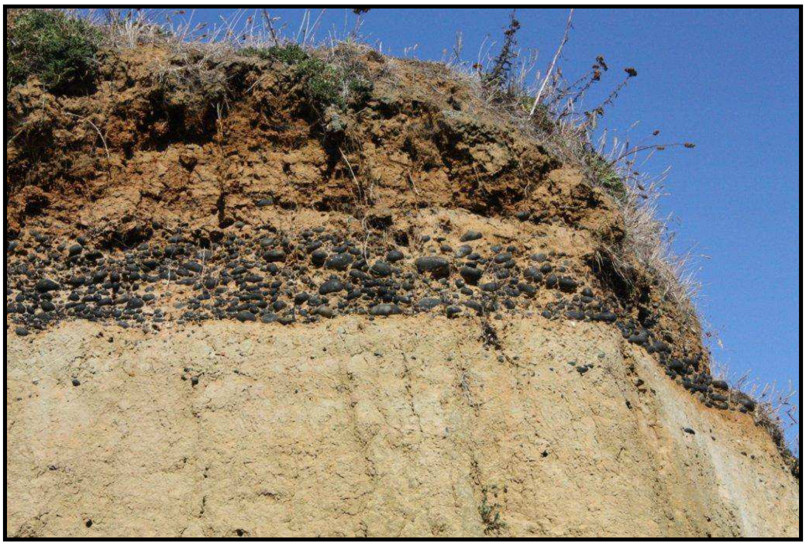
Pegwell Bay where this ship commemorates the landing of Hengist and Horsa in AD449 :the beginning of the Anglo-Saxon invasion. St. Augustine landed here in AD597. More recently this was the terminal for the hovercraft service to Calais. The smooth white Margate chalk member was unconformably overlain by the Thanet sand formation – a 20ma gap and the K-T boundary.

The K-T boundary, with a thin palaeosol between the Newhaven Chalk and the Cliffsend greensand

Day 2 found us on the beach at Swalecliffe. Spade in hand, Martin was in his element. This pile of smooth black mud was alluvium, an iron age river had flowed here while the neighbouring pile of black mud was flaky London clay in situ. This ridge contained organic matter, traces of leaves and twigs in rectangular shapes, maybe old channel fill, Iron Age fish traps...? Martin had found flints and a tusk on these beaches.



Beltinge



Blackheath pebble bed (probably beach deposit) overlain by Oldhaven Sand (shallow marine) and overlying the Woolwich formation (estuarine with glauconite formed by flocculation).

Burrow formed flint

Paramoudra flint

Here two sets of flares indicate two periods of glaciation, probably at the end of the last ice age. The chalk is Margate member and the pale line near the top is a palaeosol.

The glorious weather held until the end: the chalk, different to our own Farnham region, with periglacial features clearly displayed.

Our thanks go to Dr Graham Williams and Dr Martin Bates.

Janet Phillips

London Basin Forum and Geological Atlas

Summary of December 2011 lecture given by Dr Michael De Freitas, Imperial College, London

London's population is around seven million and produces more than 40% of total tax revenues for the UK. The infrastructure to support this makes London and its surrounding areas, one of the most intensively investigated areas of ground on Earth. Countless boreholes have been drilled for ground investigations and water supplies; many kilometres of tunnels have been excavated for railways and other utilities; immense volumes of ground have been excavated for foundations, cuttings, and quarries, and a considerable amount of geophysical surveying has been completed for commercial purposes. From all this it might be expected that the geology of London and its surrounding areas is well known - but not so!

Maps and cross sections of the London Basin show the area as a simple syncline – see Fig. 1 from Wikipedia and Fig. 2 from Sumbler, 1996.

However several various lines of information and investigation have led to a reanalysis of the Basin. Students at Imperial College discovered that the river patterns within the London Basin appeared to be structurally controlled with distinct angular bends, and multiple subparallel sections. Tunnelling had often shown that the simple cross section was incorrect – engineers had designed tunnels to travel along a simple trajectory through the Chalk but found that the Chalk suddenly disappeared, having risen higher or dropped lower - see the cross section through the Plaistow Graben (Fig. 3 below). Further, local and distinct structures, including small-scale 'horst and graben', were mapped - see the red blocks in Fig. 4 and data banks developed by contractors showed multiple, strange and unexpected trends of data when a simple trend should have been present (see Fig. 5).

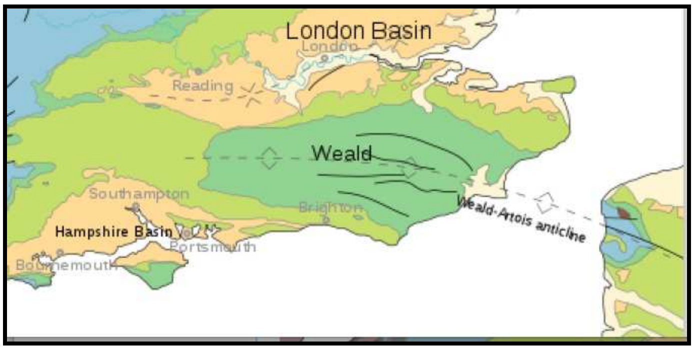


Fig. 1: Map of the London Basin taken from Wikipedia

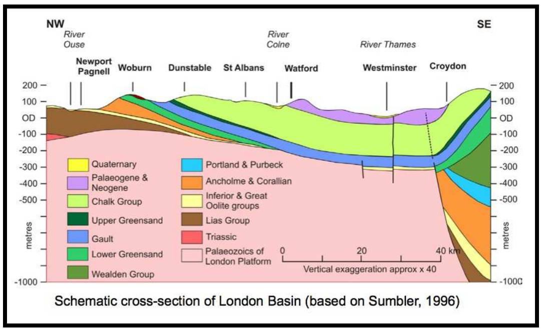


Fig. 2: Typical simple cross-section of the London Basin

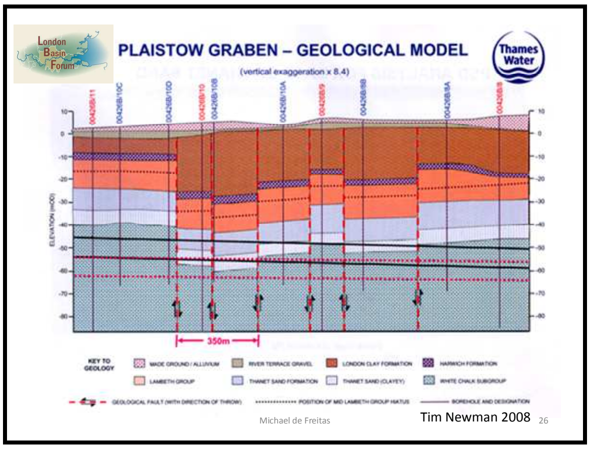


Fig. 3: Plaistow Graben; an example of local small scale structures that can develop as pull-apart basins.

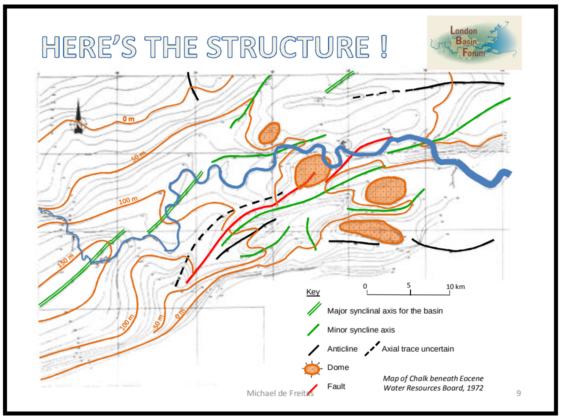
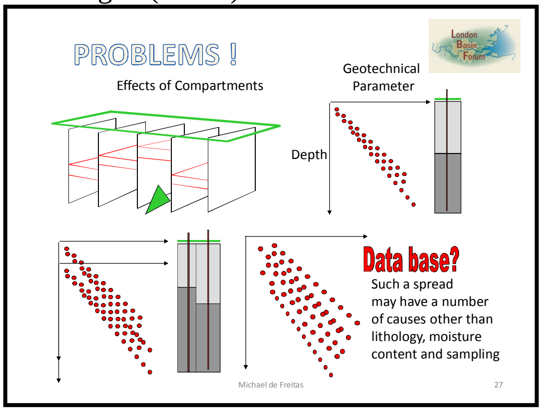


Fig. 4: The true structure of the London Basin showing the various faults & trends, domes & small anticlines.

A re-analysis of the structures and data has led to the development of a new explanation for the structures, namely that the basin in a pull-apart basin, associated with right-lateral movement along the basin axis.

There is a very large volume of unpublished, undigested and unsynthesised data for this area (basically everywhere within the M25), which no single organisation owns, and which no single company has the economic motivation to collate. The London Basin Forum and Geological Atlas will synthesise these old and new data in a format that will enable them to be used, for the first time, in scoping and funding all future major engineering and development projects in the capital and its environs, in managing risks arising from ground conditions and in assisting the contracts for all such projects.

Fig. 5 (below): Problems with data banks that have not distinguished the context of their data



The Atlas will also guide local, regional and strategic decisions for development thereby maximising returns on investment in transport, infrastructure, flood defences, water supplies, planning and development in general, and make these geologically based tasks intelligible to others, so providing an educational resource for schools, teachers and local communities,

Intended users of the Atlas include consultants, contractors and engineers, architects, planners and developers, investors and insurers, Local Councils, Regional Agencies and Central Government, teachers and scientists, community leaders and the general public. Hence for the Quaternary section it will be desirable to provide maps of what the geology was initially (for academic users) but also what is there now, i.e. left behind after the removal of the gravel (for industrial users).

It is envisaged that there will be considerable interest in the work elsewhere in the UK and around the world and that other cities will find the Atlas format a useful tool for their own future development projects.

The Atlas was to be a conventional hard-copy A3 size reference book, available also in electronic form and CD Rom. It now seems unlikely to be so and more likely to be available electronically. That will enable it to be linked to the British Geological Survey (BGS) GeoIndex software to provide a 'one-stop-shop' for those working in London and the Home Counties. The facility will contain explanatory text with maps, extensive text figures and relevant images. Maps will record features of geological, hydrogeological, geotechnical and geo-environmental significance. Many maps will be further illustrated with block diagrams showing the geology in 3D. Case histories from industry will be used to explain the relevance of the geology to planning, design, construction, supply and maintenance.

Michael De Freitas

The nature, origin and economic value of gemstones

Summary of November 2011 lecture given by Prof. Andrew H Rankin, Kingston University

1. Introduction

Since the dawn of civilisation mankind has sought out a variety of minerals, which, throughout the ages, have been much prized as objects of great beauty and emblems of personal wealth and prestige. These are what we refer to as gem minerals or gemstones. At present, some 120 minerals fulfil the generally accepted criteria to warrant classification as gem minerals; beauty (colour/sparkle), durability (chemical and physical resilience) and rarity. Of these the most highly prized are: Diamond, Sapphire, Ruby and Emerald. These, referred to as 'the big four', provide the focus of the present article.

Tanzanite, a blue variety of the mineral zoisite, is a possible candidate for inclusion in this current list. It was 'discovered' in Tanzania in 1967 and introduced by Tiffany & Co, New York, to the world gemstone market in 1969. But, as a relative newcomer, it is considered beyond the scope of this paper.

Natural pearls are also highly prized gems. However, they too have been excluded from consideration because they are organically-derived and, therefore, not true minerals in the strictest sense.

2. Origin of Gem Minerals and Synthesis under Laboratory Conditions

The origin of most gem minerals is now generally well understood. Recent advances in mineralogy and geochemistry, together with a knowledge of the geological settings of known deposits, allow us to formulate reasonable models for their geological occurrence and the processes responsible for their formation.

2.1 Primary deposits

These are formed by various igneous and metamorphic processes over the temperature range from c.300ºC to >1000ºC, or by hydrothermal processes via transport and deposition from hot aqueous fluids in the Earth's crust over the temperature range from 100ºC to 600ºC.

It is possible to simulate these natural growth conditions at high temperatures and pressures in the laboratory, even up to the pressure and temperatures that exist within the Earth's mantle. Commercial production of gem material is now possible, with laboratory-grown rubies, sapphires, emeralds, and even some diamonds, now quite widely available on the market.

2.2 Secondary Deposits

Secondary deposits are formed by weathering and erosion of rocks that host primary deposits. These form through mechanical accumulation of gem minerals at, or near to, the site of weathering (eluvial deposits), in distal river sediments, gravels and alluvium (alluvial placer deposits) and even in beach sands (beach placers).

Placer deposits are a very important commercial source for many different gemstones including diamonds, rubies and sapphires which have the ability to withstand the buffeting, abrasion and effects of chemical weathering during their transport in surface waters. A high density, or more precisely a high specific gravity (S.G.), is also an important property. This means that the more abundant minerals in sediment loads, such as quartz and micas, with a lower S.G., are transported further allowing the gems to form in heavy mineral concentrates in sediment traps along the way.

3. Properties and Sources of the top four Gem minerals

3.1 Emerald

Emerald is the attractively green-coloured variety of the mineral beryl. Its companion aquamarine is the pale-blue variety. The different colours are due to small amounts of chromium (Cr) and iron (Fe) in the crystal lattice. These, and other colour-inducing trace elements, are referred to as chromophores

Beryl, a beryllium-aluminium-silicate, is a relatively common mineral in granite pegmatites and associated hydrothermal veins, and also in some metamorphic rocks. It is the principle ore mineral of beryllium (Table 1). Most crystals are colourless, turbid or fractured in appearance. Only when they are relatively clear, free of cracks and strongly coloured can they be considered as gems. The most prized specimens are from Colombia, but important deposits also occur in Afghanistan and Africa.

Table 1 Main properties, occurrence and origin of Beryl

- Composition - $Be_3Al_2Si_6O_{18}$
- Moh's hardness of 7.5 - 8
- Colourless to green (Cr traces) to pale blue (Fe traces)
- Hexagonal crystals
- Important gem deposits- Columbia, Afghanistan
- Main gem deposit types - pegmatites and veins, schists
- Primary origin - magmatic/metamorphic

3.2 Ruby and Sapphire

Ruby and sapphire are the aesthetically-pleasing, relatively unflawed and transparent and coloured varieties of the mineral corundum, a simple aluminium oxide (Table 2; Figure 2). Large deposits of non-gem quality corundum are quite common in the form of emery which is used as an abrasive and as a major constituent of emery paper. Gem quality, and near gem-quality corundum, that warrant the name sapphire and ruby, are much rarer, but deposits are more widely distributed. Important sources are the classic alluvial deposits in Burma (Myanmar) and Southeast Asia (notably Thailand). Significant deposits are also associated with a large metamorphic belt running more-or-less the length of East Africa from Kenya through Tanzania, Malawi and Mozambique. Gem Sapphires of probably igneous origin also found in basalts from SE Asia, Australia and the USA (Montana).

Table 2 Main properties, occurrence and origin of Corundum

- Composition - Al_2O_3
- Moh's hardness = 9
- Colourless to deep red and blue- Ruby (Cr traces), Sapphire (Fe/Ti traces)
- Hexagonal crystals
- Important gem deposits - Myanmar (Burma), Africa, Thailand
- Main gem deposit types – alluvial deposits
- Primary origin – metamorphic/hydrothermal and magmatic (sapphire)

The term ruby is restricted to the deep red gem varieties of corundum in which the important chromophore is chromium. Traditionally, the term sapphire was used to describe the blue varieties of gem-corundum (iron and titanium chromophores). But, depending on the oxidation state of iron in the lattice (Fe^{2+} and Fe^{3+}) other colours, ranging from green through yellow and orange to pink, can occur. These are often referred to as 'green sapphire', 'pink sapphire' and so on.

3.3 Diamond

Diamond is the mineralogical name for one of the two important naturally-occurring crystalline forms of carbon (Table 3). It is the hardest known substance (top of the Moh's harness scale). As such it has important industrial uses as an abrasive and component of cutting, grinding and drilling tools required to work hard materials (e.g. rock drilling and polishing). Interestingly, the other crystalline form, graphite, is one of the softest minerals known.

Fig. 1. The Hooker Emerald Brooch from the Collection of the Smithsonian Institute (Natural History Museum, USA). Photo: Chip Clark
http://www.nmnh.si.edu/minsci/images/gallery

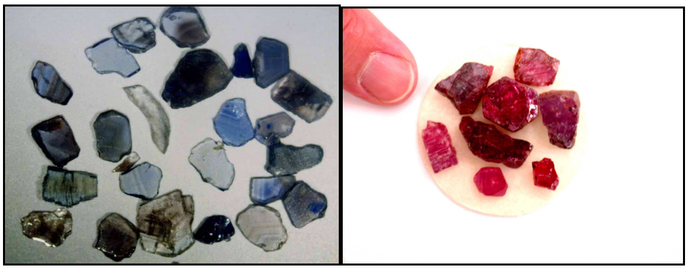


Fig. 2. Colour variations in sapphires and rubies.
Left (A) Partly polished rough sapphires from Bo Ploi, Thailand.
Right (B) Rough rubies from Chimwadzulu, Malawi.

Fig. 3. The Cullinan Heritage diamond (507 cts.) produced from Petra Diamonds Cullinan (Premier) mine, Republic of South Africa in Sep 2009. Sold in Feb 2010 for $35,300,000 – a record price for a rough diamond, http://www.petradiamonds.com/media/image-library/diamonds/ image1.aspx

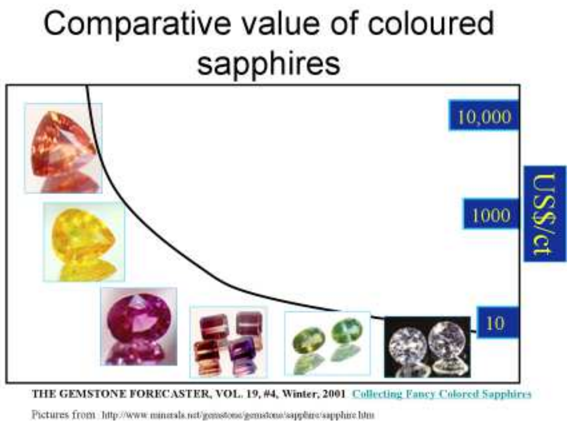
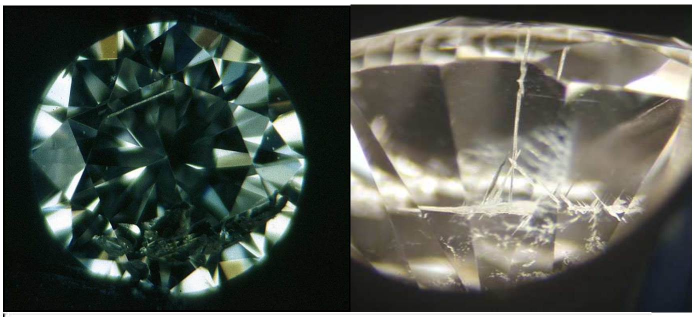
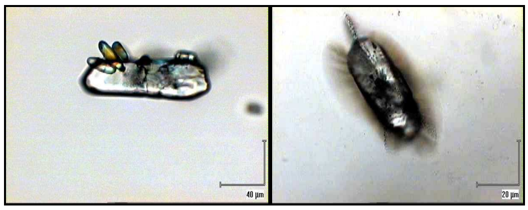


Fig. 4. Comparative 2001 prices for different coloured varieties of sapphire





Above Left: Fig. 5. Inclusions in laboratory grown and clarity-enhanced diamonds. Left (A) Laboratory grown diamond with nickel-iron rod (NW of centre) A.Hodgkinson http://www.scotgem.demon.co.uk/redsyndia.html. Right, B. Laser drilling track from top of a diamond to site of inclusions below www.gemologytools.com/html/ gt_pro_info.html

Above Right: Fig. 6. Photomicrographs showing microscopic inclusions of Topaz in corundum/sapphire from Malawi, before (left, A) and after (right, B) heating above 1500°C. Note scale in microns and radiating trails from the heat treated sample.

Left: Fig. 7. The white dwarf, BPM 37093 (nicknamed 'Lucy') in Alpha Centuarus, believed by Astrophysicists to contain a single mass of diamond at its centre.

http://news.bbc.co.uk/1/hi/sci/tech/3492919.stm
http://www.cfa.harvard.edu/news/archive/pr0407.html

Most naturally-occurring diamonds are turbid and/or grey to black in colour, or so tiny as to be fit only for industrial purposes. Gem quality diamonds are restricted to transparent crystals that are relatively devoid of visible inclusions and are either colourless or attractive shades of yellow, pink and pale blue. Inclusions of other opaque minerals give rise to the common black and dark grey colours, and trace amounts of nitrogen and boron are responsible for the pink yellow and blue colours.

Table 3 Main properties, occurrence and origin of Diamond

- Composition - Carbon (C)
- Moh's hardness = 10
- Variable colours from black to colourless; blue, pink and yellow
- Octahedral crystals with octahedral cleavage
- Important gem deposits – Africa, Siberia, Canada, Australia, Brazil
- Main gem deposit types – kimberlite pipes and alluvial deposits
- Primary origin – magmatic (mantle derived)

Diamonds originate from deep below the Earth's surface at depths between 150 and 250km, in the upper mantle, where the growth is believed to take place very slowly, sometimes forming very large crystals (Figure 3). Theses are transported rapidly to the surface by rare, volatile-rich igneous intrusions, known as kimberlites, after the type locality Kimberley in South Africa. No-one has yet witnessed a kimberlite eruption but their ascent is believed to have been so rapid that they reached supersonic speeds as they break through to the surface forming volcanic debris surrounding a central crater. Rapid intrusion is considered important in maintaining the crystalline integrity of diamond. Otherwise, they might revert to graphite which, thermodynamically, is the more stable form of carbon at the lower pressures and temperatures in the upper reaches of the Crust.

Kimberlite intrusions are very rare, and those that are diamond-bearing are restricted to ancient shield areas (>2.5Gs) of the main continental masses. Kimberlite intrusions are generally pipe-like bodies with roughly circular cross sections at outcrop which seldom exceed >1km in diameter. Historically important kimberlites of South Africa still produce some exceptional stones (Figure 3). But Botswana, Angola, the Democratic Republic of the Congo (DRC) and Tanzania are now major African producers, together with Namibia where beach placers are exploited. Other important kimberlite deposits are mined by open pit methods in Siberia and Canada (since the 1990s). The Argyle mine in Australia has been a notable producer since the 1980s, especially of pink diamonds, though the host rocks here are lamproites rather than true kimberlites in the strictest sense. There has been some diamond production from alluvial workings in Brazil and India but, to date, no kimberlites have been economically exploited from these areas.

The high value placed on diamond is a consequence of their extreme rarity even in the most productive diamondiferous kimberlites. Of the 5000 or so known kimberlite pipes, only about 25 contain sufficient concentrations of diamond to be economically mineable. Their economic viability depends on many variables such as the size, distribution and the proportions of gem quality to non-gem quality material. Reliable estimates of economic grades are, therefore, difficult to define. However, published data for several producing African kimberlite pipes suggest working grades of between 50-150 cts per 100 tonnes which equates to a production of just 1 to 3g every 10 tonnes of kimberlite mined.

4. Factors that Influence the Economic Value of the top four Gem Minerals

Supply and demand has a key influence on the economic value of uncut stones. But for cut stones the value depends largely on their size, their clarity, depth of colour, and with how well the crystal has been cut. This is especially true for diamonds whereby the value of fine, cut, and colourless diamonds is quite simply determined by these four parameters.

4.1 The Four Cs

The four Cs refer, with particular reference to Diamond, to the use of Colour, Clarity, Carat weight and Cut (Table 4).

Table 4 The four Cs used in the certification of gem quality cut diamond

- **Colour**. Comparison is made against a set of labelled reference stones showing subtle variations in colour from almost colourless (C, D, …) to very pale yellow or grey/brown colour tints (...M, N…). Lower lettered stones are valued more highly.
- **Clarity**. Using a x10 hand lens and/or microscope the size and distribution of any inclusions and flaws are assigned a scaled rating from Flawless (F) through to Very Small and Small (VS and S)

to Imperfect (I) in which inclusions are visible to the naked eye. The fewer and smaller the inclusions, the higher the value of the stone.

- **Carat weight**. One carat (1ct) = 0.2g. Each carat is divided into 100 points (e.g. a 85 point stone would equate to 0.85ct). The greater the weight the higher the value of the stone.
- **Cut**. There are various ways in which diamonds may be cut to maximise their sparkle. In all cases slight perturbations in the symmetry, proportions and interfacial angles of the facets can affect these properties and thus reduce the value of the cut stone.

A similar approach could be used to evaluate rubies, sapphires and emeralds. But it is much more difficult for gemmologists to agree and a suitable colour grading system is needed to evaluate the full range of colours encountered. Trends in fashion, particularly for coloured stones, can exert an important and sometimes transient influence on commercial value, as illustrated in Figure 4.

4.2 Integrity, Enhancements and Natural vs. Laboratory grown crystals

Before a proper evaluation of a good quality cut stone, it is necessary to confirm its mineralogical identity and integrity by posing the following questions:

Is it real or a substitute?

Is it natural or laboratory-grown?

Has it been enhanced in any way?

The experience and integrity of gem dealers and jewellers plays an important role in this assessment. Confirmation of mineral identity and recognition of common substitutes for diamond (e.g. synthetic cubic zirconia and moissanite), emeralds, rubies and sapphires (e.g. coloured lead glass a.k.a. 'paste') can be carried out routinely with the aid of standard gemmological instruments. But at, or near, the high end of the market, reports on integrity and likely provenance of individual stones are usually commissioned from professional gemmologists based on more detailed optical examination and laboratory tests. Increasingly there is a need to resort to more advanced laboratory methods to detect the latest attempts at artificial enhancements.

Many will argue that there is nothing wrong with enhancing the beauty of a gem mineral, so long as this is disclosed. This may also pertain to laboratory grown (synthetic) gem minerals which are often as beautiful and spectacular as their natural counterparts. It should be noted, however, that a much lower value would usually be assigned to laboratory-grown stones of similar quality to natural ones for much the same reasons that an original penny black stamp is far more desirable and valuable than a perfect photocopy.

Some of the examples of treatments and ways in which they may be recognised are outlined below.

4.2.2. Emerald

Many gem quality natural emeralds have imperfections in the form of partially healed fractures and channels. These tend to scatter rather than transmit and reflect light from cut stones, thus reducing their sparkle and value. These effects may be minimised through impregnation with natural and synthetic oils with refractive indices similar to those of the host beryl. Natural oils especially have the tendency to degrade over time leading to an unwanted brown-yellow discolouration. So, it is important to check for signs of 'oiling' using a hand lens or optical microscope.

The much prized Colombian emeralds are distinguishable from those from other localities and laboratory grown specimens based on their characteristic fluid inclusions. Fluid inclusions are droplets of the fluids, from which a mineral formed or recrystallised, and have become trapped and preserved, within the crystal, during its primary growth or recrystallisation. Research has shown that Colombian emeralds formed from very salty hydrothermal fluids. This is evident from the common presence of three phase inclusions (brine solution, cubic salt crystal and vapour bubble). Sometimes these are visible with a hand lens, but even those less than 1/100th of millimetre are recognisable under a microscope.

4.2.3 Ruby and Sapphire

A large proportion of sapphires and rubies currently available on the market have been heat treated to very high temperatures (to ≥1500ºC) to improve their colour. Otherwise colourless, murky grey or dull-coloured corundum, sapphires and rubies can be turned into deep blues, reds and other attractive colours. This causes partial melting or disintegration of mineral inclusions, which may be manifest by wispy veil-like micro-fractures emanating from the original inclusions, using a hand lens (Figure 5).

Natural, unheated sapphires and rubies may also contain fluid inclusions containing both liquid and gaseous carbon dioxide (and water), visible as separate phases at room temperature. On gentle warming to >31ºC (above the critical point of pure CO_2), the three phase inclusions become two phase with CO_2 liquid and vapour merging to form a single supercritical phase. The presence of such CO_2-bearing inclusions can be used to distinguish them from laboratory grown crystals and also heat treated specimens that would burst open these high pressure inclusions.

In recent years, artificially induced diffusion of trace amounts of Beryllium though the crystal lattice of dull-coloured sapphires, has been shown to change their colour to more attractive and desirable shades of orange. The influx of undisclosed Be-diffused specimens onto the market has caused much concern especially as detection is only really possible using advanced and sophisticated analytical methods (e.g. Inductively Coupled Mass Spectrometry). These are generally unavailable or too expensive to apply routinely in commercial gem-testing laboratories

4.2.4 Diamond

Gem quality laboratory-grown diamonds of up to several carats in weight are currently available on the market. These are usually marketed as such so as not to confuse them with their natural (and more valuable) counterparts. Where necessary the distinction between natural and synthetic diamonds and diamond stimulants can be made. This is based on well-established optical and physical tests, for example the characteristic presence of magnetic metallic nickel-iron inclusions in laboratory-grown crystals (Figure 5A). Bespoke gemmological instruments specifically for this purpose, such as Diamondsure™, are now available.

Laser may be used to 'drill-out' unwanted visible inclusions to enhance value. The resulting fractures and cavities may then be filled with fluxes and high RI glasses. The tell-tale signs are usually not difficult to recognize for the experienced observer (Figure 5B), though more recent applications of confocal laser drilling is more worrying as it leaves little or no visible trace.

The colour of diamonds can be enhanced in a number of ways to improve or emulate those of desirable 'fancy colour' natural stones. These include irradiation with neutrons (green colour), combined heating and irradiation (yellow, orange, green, pink, and violet) and high-temperature-high-pressure, HPHT, treatment (producing clear colourless stones from murky brown ones). In such instances disclosures should be made by professional gem dealers, but this is not always the case, or indeed possible. Until recently, detection was very difficult, but with recent advances in the application of advanced spectroscopic methods this is increasingly possible.

5. The future of Gems

There are a number of key issues that the gem mining industry and trade need to address to ensure public confidence in the future of gemstones as valued commodities.

The controversy and immorality over the sale of 'blood diamonds' to fund wars in conflict areas of the world in the 20th century lead the UN to pass resolutions to halt their influx into the market. The industry responded positively with the Kimberley process (http://www.kimberleyprocess.com/) a process aimed at eliminating trade in diamonds from these areas. Inevitably, some stones may still slip through the net because, at present, it is almost impossible to distinguish them from those from legitimate sources. Some sort of chemical fingerprinting or other means of discrimination, which could also be extended to other gems, needs to be established with major producers taking the lead on this. Similarly, issues over unethical sources of other gemstones also need to be addressed, and in particular the increasing trend and desire to purchase 'fair-trade' gems and jewellery from proven ethical and sustainable sources.

Manufactured gemstones with the beauty quality attributes of the best natural stones are quite likely to be produced more efficiently and cheaply in future. This raises two issues: i) Will the market trend shift more towards these sources with a concomitant lowering of prices overall? and ii) With increased sophistication and subtlety in implanting the chemical and physical attributes of natural stones into laboratory grown examples, more advanced methods of detection will be needed. How widely available and cost-effective will these be?

If demand for gems continues at its current rate, new natural resources will have to be found to replace those that have been exhausted. Undoubtedly, worldwide, there are many deposits yet to be discovered, but where, by whom and at what cost remains uncertain. What is known is that as we explore beyond the confines of our planet, far, far into the future, we will be awash with diamonds! Scientific studies suggest that at the extreme pressures towards the centres on the methane-rich outer planets of the solar system, diamond is stable to the extent that it is likely to be raining diamonds on Neptune (Reported by Benedetti & Jeanloz, in Science, Oct 1, 1999). Still further afield, some 50 light years away, in the Alpha Centaurus constellation, the dying remnants of a star has collapsed into a white dwarf, 400km in diameter and composed of a single crystalline mass of diamond weighing some Billion-Trillion-Trillion (10^{34}) cts. (Reported in 2004 by Harvard-Smithsonian Astrophysics Team). This is a sobering thought when one considers that we, on Earth, put such a high value on probably the most common of all known gemstones in the Universe.

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