GEMSTONES
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by

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The only feature which characterises minerals which have gem varieties is their suitability, which depends mainly on beauty and durability. For beauty it is fortunately not possible to offer scientific criteria, but durability when expressed in mineralogical or gemmological terms means that the mineral or stone must not be too soft (in practice greater than 5 on Mohs' scale of hardness) and must not have too good a cleavage or tendency to split along certain planes. It should be noted, however, that diamond cleaves rather readily parallel to the octahedral faces and indeed could not be easily fashioned into a cut stone were it not for this weakness parallel to its direction of greatest hardness.

From the commercial point of view the most precious stones, and those which best hold their value, are diamond, ruby, sapphire, emerald and opal; most of the other gemstones suffer under the rather unfortunate name of "semi-precious stones" and their value fluctuates according to fashion. Thus in Victorian times agates were in great demand and fetched a good price whereas in the mid-twentieth century their silver mounts were prized more than the stones themselves.

Two other matters which affect the value of a gemstone are its rarity and—for coloured varieties—the exact hue and depth of colour. Thus a sapphire to be prized should be cornflower blue and not so dark as to appear virtually opaque. Another factor which is now important is the modern manufacture of synthetic stones—not fakes or the more cunning simulants, but man-made copies of the real thing differing principally in being too perfect. It is a truism to say that the vast majority of natural gemstones have minute or microscopic flaws or impurities of one sort or another (and the modern trickster has had to devise ways of making his synthetic stones equally impure). So here we come to a slight ethical dilemma: a one carat deep-red Burma ruby might cost £1000–£5000 whereas a cut synthetic ruby of the same weight could be obtained for less than £1.

The derivation of the international unit of weight for gemstones, the carat, gives an interesting insight into the long history of gem trading. Dealers could not afford to trust the weights produced by other dealers with which to weigh and price the stones, and likewise their own weights were similarly distrusted. A solution was found in the seeds of a tree grown in those Mediterranean lands which saw the development of gem trading some 2000 years B.C. The seeds of the locust bean or carob tree (*Ceratonia siliqua*) were shown to be remarkably uniform and the term "carat" is derived from their name. It is now defined more precisely as 0.200 g. (The use of the term with reference to the purity of gold is of more recent origin and comes from the original weight of the Roman gold coin named *solidus*; the content of fine gold in this coin was later reduced from 24 units to $20\frac{1}{2}$ and later to 20 and 18). Thus we are dealing with items selling for up to £1000 for 1/40th of an ounce and with such high monetary values all forms of trickery and simulation have been rife for centuries.

One of the earliest methods of faking was to use coloured glass (known in the gem trade as "paste"). This led to the use of refractometers in gemmology, instruments for measuring the refractive index of cut stones. The refractive indices of normal glasses are much lower than those of most gemstones; they can be raised by the addition of lead or thallium to the glass but the latter then becomes noticeably soft. A swifter distinction of paste can be made by an experienced gemmologist by its being warmer to the touch than a real gemstone—scientifically this is the result of the greater thermal conductivity of the crystalline gemstones compared to glass.

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Another universal and simple test is that of hardness. Mohs' scale grades all minerals from 1 (talc) to 9 (corundum) and 10 (diamond): glass, being a metastable state—a liquid, typically has a hardness of around $5\frac{1}{2}$ (so the market trader's statement that "it must be diamond—it scratches glass", is a particular non sequitur). When testing the hardness of a gemstone though, it is important to start with a standard which is definitely softer and work up to harder materials, and also to scratch the gemstone in an inconspicuous place. It is bad enough to have to shatter someone's illusion that their stone is a valuable ruby, without returning it to them with a large scratch-mark across the table facet!

There are two facts that everyone knows about diamonds: it is the hardest natural crystalline substance known and when cut as a gemstone it displays an intense "fire", i.e. strong dispersion. This property of splitting white light into its spectral colours is shown by most transparent materials. In the extreme case of diamond which has a refractive index of 2.451 for violet light and 2.407 for red light, the dispersion has the value (the difference for these two wavelengths) of 0.044. Geometrical consideration of the path of a ray of light through a gemstone will show that the greater the distance of the light-path within the stone, the greater the apparent dispersion observed on the exit of the light. Thus to obtain strong "fire" firstly the gemmologist must use a stone with a high dispersive power (e.g. diamond), and secondly the stone must be so cut and facetted to give the longest possible light-path, and thirdly the cut must be such that light entering through the main facet is refracted and reflected and eventually returns, showing maximum dispersion, cut in a suitable direction to catch the eye (Fig. 1). The proportions of the various facets and the angles between them to obtain maximum brilliance are unique for the diamond; they are different for other materials with different refractive indices.

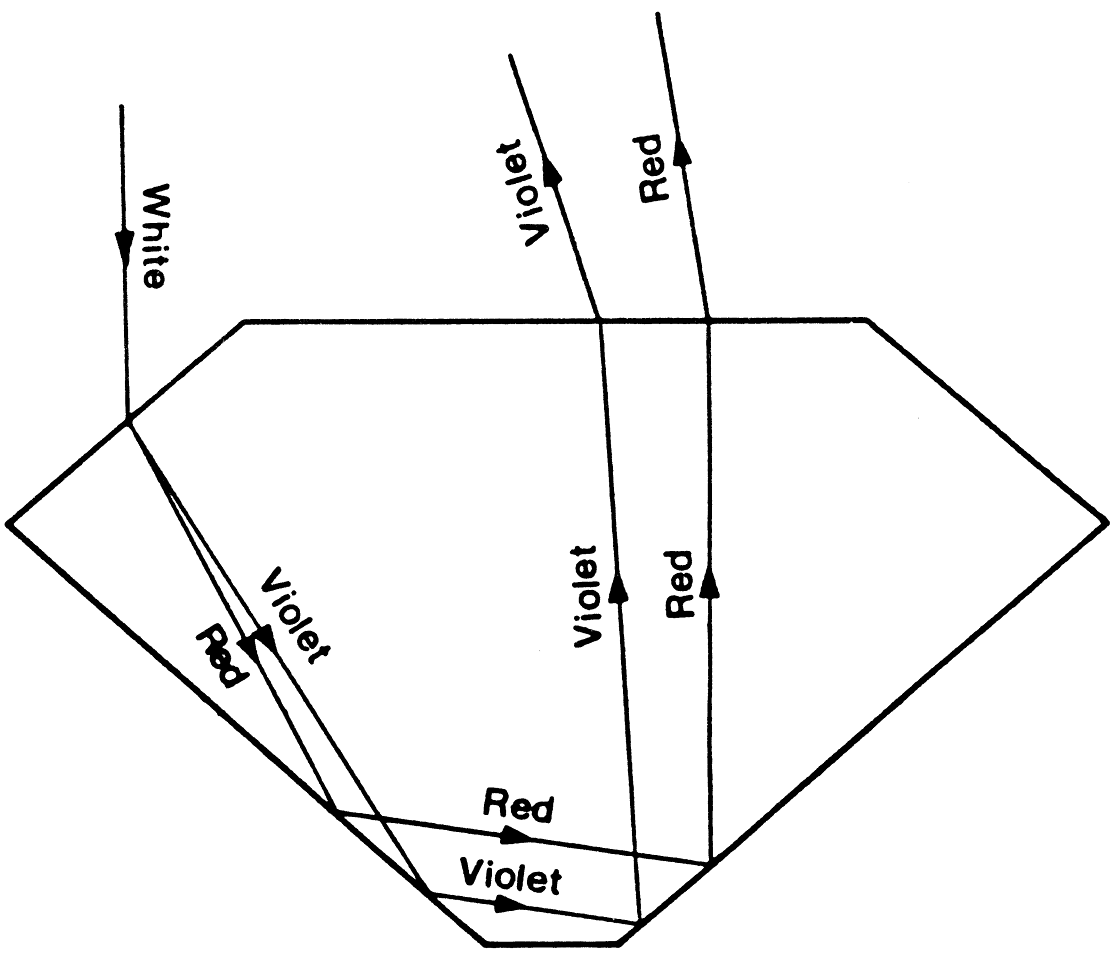

Fig. 1. A typical light-path through a brilliant-cut diamond, showing dispersion and total internal reflection.

Although diamond is the gemstone with the greatest dispersive power, other brilliant stones are to be found in synthetic materials. Thus synthetic rutile (TiO_2) has a dispersion of 0.280, i.e. six times greater than diamond. It is, however, never obtained in a completely colourless state, being slightly milky, and it slowly becomes oxidised to light yellow. Some 25–30 years ago the synthetic compound strontium titanate was produced: this is water clear, has a refractive index of 2.41 and a dispersion of 0.19, i.e. four times greater than diamond. It presents such a fabulous appearance of fire and brilliance that it is marketed under the tradename of "fabulite". This material is a real danger to the public but a potential purchaser has to remember that it looks too good; it presents too much fire for a diamond. As always if one thinks a bargain is to be had in gemstones, that is the time to stop and think; one almost never will be offered such a bargain. One pointer here is that the hardness of strontium titanate is only 6. But alas one cannot test a cut stone for hardness in a jeweller's shop; even if it is examined with the aid of a hand lens suspicions will be raised that some sleight-of-hand and substitution may occur. The only solution here is to put one's faith in a High Street jeweller (preferably an F.G.A.) whose trade depends on his knowledge and reputation. More effective diamond simulants now include cubic zirconia with a hardness of $8\frac{1}{2}$ and a dispersion of 0.04. To distinguish these materials, the gemmologist must have recourse to electronic instruments which rapidly measure the thermal conductivity or other distinctive physical property.

The synthesis of gem materials can really be said to have started in 1877, when Verneuil found that corundum (Al_2O_3) synthesized by him in an oxy-hydrogen flame at around 2000 °C could be produced as ruby by the addition of some 1% Cr_2O_3. Sapphire was first synthesized in a similar fashion (1902) by the addition of Fe_2O_3 and TiO_2; green stones have been produced by adding vanadium and yellow stones by adding about 3% NiO. Synthethic emeralds have been produced since the 1930s; in general they are simply too good compared with most natural emeralds which typically contain abundant bubbles and inclusions of all sorts, though the synthetic stones have characteristic veil-like inclusions. Synthetic gem diamonds have now been produced by the General Electric Co., of New York, but have proved too expensive for commercial jewellery (synthetic industrial-grade diamond grit is now readily produced and 30–400 mesh material has been sold for as little as £2 per carat). Synthetic opals, the last of the "big five" to be produced, have recently come on the market but are somewhat unconvincing on close inspection.

An early form of simulation lay in the production of doublets or triplets. Initially, a doublet purporting to be of ruby for example, consisted of a thin layer of precious ruby cemented to a base of relatively worthless, colourless corundum. Unmounted, the join was easily visible, but when mounted in a ring, the metal shielded the join and the brilliant colour of the ruby flooded the whole stone with red light. Any tests as to hardness or crystal structure, etc. were useless as ruby is merely the red gem variety of the mineral corundum. However, careful examination could reveal the presence of the intermediate cement layer, by the presence in it of microscopic bubbles. Other doublets use synthetic corundum or more commonly synthetic spinel ($MgAl_2O_4$) as the base. A triplet may consist of two such layers of spinel with a sandwich filling of green glass, simulating an emerald. For most such stones, the natural materials (ruby, sapphire, emerald) contain microscopically observed straight growth lines or inclusions arranged in a hexagonal pattern (reflecting the symmetry of these minerals) whereas any synthetic phases have curved growth lines and contain tiny air bubbles.

The cause of the play of colours shown by precious opal is now known to be layers of closely-packed minute silica-spheres which produce a diffraction grating effect. Thus the colour of opal is a surface phenomenon; if one looks through an opal it has a dirty yellow appearance. In view of the cost of precious opal it has thus become the accepted practice to cut thin slivers of the material which to be easily mounted are then stuck to a layer of black plastic thus giving an opal doublet. In addition, to safeguard their polished surface, opals may be topped by a layer of quartz, forming an opal triplet. (Note: this is a correct way of conserving a scarce and expensive material and not to be confused with the doublets and triplets in the simulants mentioned above).

Diamonds were known to the Romans, but they used them only as hard stones or abrasives. They are first recorded in use as gemstones in the XIV century, but were not considered of exceptional value or interest. Their fortunes changed following the discovery of diamonds at Jagersfontein, near Kimberley in South Africa, in 1870. Here diamond occurs in the "blueground" overlying fresh kimberlite and amounts to only 1 part diamond for 2 million parts of blueground. As was the custom, each prospector was allowed to work a 20 square feet claim (at a charge of £20/month). By 1874 a series of cables was rigged to allow direct access to each claim but after two years the whole complex was bought out by Cecil Rhodes and De Beers and eventually became the Kimberley "Big Hole", until recently the deepest open hole on Earth. Ever since the Kimberley diamond find, the price of gem diamonds has tended to rise steadily due to the development of a powerful and effective cartel. During the Second World War, one item the Soviet Union was forced to import were industrial diamonds. Since the war, some 5000 geologists have been trained in the U.S.S.R., a good proportion of whom were sent to Siberia—to prospect for diamonds. Some 25 kimberlite pipes have now been discovered and the Soviet Union is now not only self-sufficient in diamonds but exports to the West. Indeed more than one quarter of all gem diamonds on sale in London and Amsterdam are of Soviet origin. They could effectively challenge the pricing of international markets but it is the Soviet interest to maximize their hard currency earnings by maintaining the price levels.

In conclusion, in the harsh commercial world of gemstones, it is evident that bargains are rare. On the other hand it must be remembered that the "value" of a gemstone, rough or cut, is simply what someone is prepared to pay for it. The true value lies in the beauty, symmetry, colour, and other properties and their proper appreciation and enjoyment.

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