13.1 Colour Treatment

The most important determining factor in the value of a coloured gemstone is (surprise!) the colour. Aficionados can and will accept less than perfect clarity – and for some gemstone types, will insist on it (see Chapter 12.12). Colour, on the other hand, is nonnegotiable. You have likely noticed this in your own gem rough buying experience: differences in hue, saturation, and tone can drive the price up or down by a factor of ten or more.

For this reason, gem dealers have developed a variety of treatments for improving colour, and the potential for substantial economic gain has prompted them to subject their treasured rough to some fairly stressful situations. Modern gemstone colour treatment comes in three essential flavours: heating, irradiation, and diffusion.

Heating or "firing" involves raising the gemstone to high temperature, usually in an oxygen-rich or oxygen-poor atmosphere. Treatment temperatures range from a few hundred to a couple of thousand degrees Celsius, applied over a period of minutes to hours to days. This can involve a non-trivial investment in special equipment, and the process is not without its risks (see Section 13.1.2 below).

Radiation treatment subjects the gemstone to energetic photons (gamma rays) or subatomic particles, such as neutrons and beta particles (the historical name for high speed electrons). Some natural radiation treatment involves alpha particles, again a historical name, this time for energetic nuclei of helium atoms (see page 160).

The third type of common treatment aimed at improving colour is **diffusion**, in which the gemstone is heated to near-melting temperature in an environment rich in chromophore elements such as titanium or iron (see page 85). Shallow *surface diffusion* has been around for decades, but recently, much deeper and more difficult to detect bulk or *lattice diffusion* techniques have appeared.

Foiled Again

Actually, there is one more colour treatment beyond heating, radiation, and diffusion: foiling or surface coating. This involves the application of a thin film to the outside surface of the finished gem, often by vacuum deposition techniques. I hesitate to include surface coating among gemstone colour treatments, since it emphatically does not alter the body colour of the stone. I also hesitate because the resulting gems look, in my opinion, emphatically kitschy.

You have probably encountered surface treated gemstones in the form of *Mystic Topaz*, a trade name for colourless topaz with a thin, metallic surface layer applied. When done properly, such a layer will display iridescent interference effects, much like a soap bubble (see also Section 12.7.4). Unfortunately, the coatings are thin, mechanically delicate, and subject to chemical attack from common liquids such as household cleaners. Oh, and did I mention that they look kitschy?

Mystic topaz may be the best-known type of surface-treated gemstone, but it is by no means the first to come down the pike. Some two thousand years ago, Pliny the Elder referred to the application of foil to the back of gems to enhance their appearance, and the practice predates Pliny by almost as much time as he predates us (see "Ancient Treatments, Ancient Fraud" on page 154).

More recently, the foiling of gemstones to improve reflectivity and colour was a common and accepted practice in the 18th and 19th centuries. A basic understanding of optics, which you can glean from Chapter 11, and a glance at the gem designs of the time, particularly the rose cut (page 241), should make it obvious why help was needed. The revolution in gemstone design at the beginning of the twentieth century essentially doomed the art, and true "foil backs" are now a collectors item…emphatically kitschy, but still very collectible.

13.1.1 How Do Colour Treatments Work?

Heat treatment for colour relies on the fact that many gemstones derive their body colour from external trace contaminants, and it is the exact oxidation state of these interlopers that determines the resulting hue, saturation, and tone. Altering the oxidation state of a gemstone's chromophores will alter its colour. Chapter 12, and in particular Section 12.3.2, has a great deal more to say on this issue.

The gases used in heat treatment are either *oxidizing*, in other words oxygen-rich, or *reducing*, which is oxygen-poor. Typically, an oxidizing atmosphere will remove electrons from the chromophore, changing Mn^{++} to Mn^{+++}, for example. A reducing atmosphere has the opposite effect. Thus, much aquamarine has been heated in a reducing atmosphere to convert ferric chromophores (Fe^{+++}) to ferrous (Fe^{++}). This drives off undesirable yellow-green tones (see also Table 12-2).

Heating can alter the colour in other ways, for example by dissolving impurities such as rutile needles in sapphire. Of course, dispersing inclusions via heating will enhance clarity as well (see Section 13.2 below). Heating can also improve colour by allowing the chromophores to move about and become distributed more evenly, hence reducing the effects of banding and zones.

Irradiation operates in a completely different way. Chapter 11.3 describes how light interacts with matter, specifically how the incoming electromagnetic wave "shakes" the crystal lattice and produces the optical effects we observe. Furthermore, Chapter 12.3.1 explains how subtractive colour arises due to absorption of specific wavelengths of incoming light.

Radiation treatment of gemstones combines these two principles. Bombarding a crystal with energetic gamma rays or high-speed subatomic particles produces damage in the structure of the crystal lattice. For example, an atom can be knocked out of its usual location and an electron be trapped in the resulting "hole." As with the simple radio antenna described in Chapter 11.3.2, the electron reacts to the incoming electromagnetic wave and jiggles back and forth. This jiggling dissipates the energy of the wave, and the light is absorbed. The interaction of the electron with the wave and its surrounding atoms allows absorption over only a narrow range of wavelengths, however. The result is a "colour center," a small zone in the crystal which absorbs a certain colour of light.