Stars, Stripes and Spangles

First published in *Lapidary Journal*, August 1992

Gather enough of the right gemstone inclusions in the right directions, and suddenly you have a gemstone that is far out of the ordinary.

One person's flaw can be another person's asset. Many people with an over-large nose would consider plastic surgery. Comedian Jimmy Durante made his "schnozz" his trademark. Niccolo Paganini, 19th century Italian violinist, had incredibly flexible finger joints, possibly due to a bone disease. The violin technique he developed as a result revolutionized the playing of that instrument.

Internal gemstone "flaws"--or, more accurately and less pejoratively, inclusions--are often scorned by the unknowledgeable. Yet gemologists know that, like human "flaws," inclusions can be assets. Inclusions can help separate genuine from imitation (gas bubbles are not found in diamonds), signify a particular gemstone species ("lily pad" type fractures indicate peridot), and even identify an individual gemstone (one reason GIA's Gem Trade Laboratories provide a diagram of a diamond's inclusions on their reports).

These aspects of gemstone inclusions are invaluable for jewelers, gemologists and lapidaries. But there are times when a gemstone's "flaws" are transformed into an asset even laypersons can appreciate. That is when the inclusions create phenomena.

Phenomena are the "special effects" sometimes exhibited by gemstones when light interacts with the stones' structures or the material in them, for example, the opal's play of color. But phenomena such as aventurescence (the spangled effect seen in some gems), chatoyancy, and asterism appear when light strikes the inclusions in a mineral.

Inclusions--broadly--are foreign substances or growth characteristics inside a mineral: solids, such as crystals, needles (which can be long fine crystals or hollow growth tubes), gases, liquids, fractures (irregular internal breaks), and cleavages (breaks along crystal planes). Not all inclusions create phenomena--in fact, most do not. The kinds of inclusions that give us the phenomena we are talking about here are needles and flat, plate-like crystals.

Phenomena-producing inclusions develop while the mineral is growing, often through the process of exsolution. Exsolution occurs when one kind of mineral separates from or settles out of another due to a change in temperature.

Minerals grow deep in the Earth where temperatures are extremely high. At high heat, atomic bonds in the host mineral are weaker and the molecules (which are clusters of atoms) are farther apart than they are at surface temperatures. Molecules of foreign minerals (those other than the type that make up the host crystal) can slip into the growing gem's crystal structure with room to spare. But as the host mineral cools, the atomic bonds strengthen, the molecules draw together, and the foreign molecules are squeezed out. They are forced into relatively "open" areas in the host mineral's crystal structure along crystal planes.

The structure of the crystal may be such that the growing inclusions can orient themselves in only a few directions. There may be only one direction in which the foreign molecules find room to settle. As the molecules of the inclusions-to-be exsolve and form crystals and needles, they are forced into these fixed directions and locked there by the crystal structure of the host.

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Exsolution may create long fine crystals we describe as needles. But needle-like inclusions may be hollow growth tubes instead of solid crystals. Growth tubes occur when minute crystals settle on the face of a growing crystal and force the growth of the host crystal around them. The altered growth pattern continues after the foreign crystal has been bypassed, creating a long narrow void. (It would be like building a brick wall around a rock, then continuing to add to the height of the wall without ever bricking over the space between the walls.) In some cases, the guest crystal is continually buoyed up by the growth of the host material and so leaves a void behind it. (Imagine every new tier of bricks in the wall lifting the rock a little higher, until the rock is hanging over an empty chamber in the wall.) Naturally growth tubes are aligned along the direction of growth in a crystal.

There may be only a few crystals or needles trapped inside a gemstone during its growth or there may be countless thousands. If there are only a few of them, they may be of interest only to gemologists who use them to identify the stone in which the inclusions are encased. However, if there are enough inclusions in an otherwise transparent mineral, light reflecting from the surface of the inclusions can result in phenomena.

Stone Spangles

If you have ever visited any of the innumerable tourist traps across the US, especially if you were a child of, oh, eight or nine at the time, you are familiar with a sparkly, copper-colored material called goldstone. It is set into tie tacks, cuff links, earrings, bracelets and just about anything else you care to name. Goldstone, so the story goes, was discovered/invented accidentally by a clumsy Italian glassmaker centuries ago, when he knocked/spilled a pot of copper filings into a vat of molten glass. Because "accident" in Italian is *aventura*, the name for the spangled effect became *aventurescence*.

Aventurescence occurs in natural gem materials as well as goldstone glass. Two of the best known gems showing the phenomenon are aventurine quartz and sunstone, a type of feldspar. In aventurine quartz (which is named for the phenomenon), flat crystals of mica, fuchsite (chromium muscovite), hematite or goethite may create a spangled, glittery effect. The aventurescence is a different color depending on the included mineral: mica produces a silvery or golden sparkle; hematite and goethite glitter red, while chromium muscovite sparkles green. In sunstone, metallic platelets of minerals such as hematite, goethite or copper create a golden or coppery aventurescence.

Although sparkling inclusions may be caught up randomly during the growth of a host crystal, in the best aventurescent stones, the included crystals have formed by exsolution. Because they are all oriented in the same directions (along crystal planes), light entering the stone reflects from them all at the same time creating broad patches of glitter.

As attractive as aventurescence is in a gemstone, there is another inclusion-dependent phenomenon that makes all others pale by comparison--chatoyancy.

Here's Looking at You, Kid

The cat's-eye effect, or chatoyancy, is caused by the reflection of light from numerous needle-like inclusions in a gemstone, needles which may be solid or may be hollow tubes. When light enters the chatoyant gemstone and reflects from the surface of these needles, it creates a silky sheen.

Sheen does not an eye make, however. That happens in the cutting. Cutting cat's-eyes into cabochons concentrates the sheen across the apex of the stone. This is similar to the effect you see when light strikes the curved surface of a spool of silky thread. The concentration of light is sharpest and brightest at the highest part of the curve, that part

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closest to the light. As you might expect, the height of the cab affects the sharpness of the eye: the higher the cab, the sharper the eye; the lower the dome of the cab, the more diffuse the cat's-eye.

Cutting is critical to the quality of a cat's-eye in other ways as well. First, the stone must be cut so that the included needles are at 90º to the direction of the eye, just as the threads on a spool are at 90º to the length of the spool. Because cat's-eye are often cut into ovals, the direction of the "pupil" of the eye is commonly along the length of the stone. Second, the base of the stone must be parallel to the needles. If it is cut at an angle to the needles, the dome of the stone will also be at an angle and the eye will always be focused off the top of the stone--making it less enjoyable.

Many gemstones produce cat's-eyes: beryl, apatite, scapolite, tourmaline, quartz. But the winner, hands down, is the gem mineral chrysoberyl (which is also well known for its other phenomenal variety, alexandrite). In fact, when the term cat's-eye is used without a gemstone species name, it is understood to be a chrysoberyl cat's-eye. Because of the fineness of the needles in chrysoberyl, the eye is sharper and the appearance of the stone "silkier" than is the case with many other kinds of cat's-eyes.

The needles in a chysoberyl cat's-eye are usually described as hollow growth tubes. However, John Koivula, senior staff gemologist at GIA and an expert on inclusions, questions this explanation. Growth tubes, he explains, usually vary in diameter due to the different sizes of the crystals causing them, and they are often very coarse. But the needles in chrysoberyl cat's-eye are so delicate that Koivula, no slouch with a microscope, has not been able to get enough magnification to identify them. "The uniformity in size suggests exsolution rather than growth blockage," he says.

Growth tubes are responsible for the cat's-eyes in other gemstones, such as tourmalines. Because of the coarseness of the needles, the eyes of these stones are often less well defined, or fuzzier, than the cat's-eye in chrysoberyls.

Crossed Eyes

In cat's-eyes, the included needles are oriented in only one direction in the crystal. However, in other gemstones, needles may exsolve, or settle out, of the host mineral into two or more crystal planes. As a result, when light strikes these inclusions, it creates two or more bands of reflected light or eyes. When the stones are cut into cabs, these bright bands intersect at the apex of the dome of the stone and form stars. The effect is called *asterism*.

Asterism occurs in a variety of materials. However, it is most well known in the corundums, especially ruby, sapphire and black star sapphire. Perhaps the next best known are the star garnets.

Garnets form in the cubic crystal system and needles (often ilmenite) formed by exsolution usually orient themselves in two directions creating a four-rayed star. In corundum, needle-like inclusions (often rutile) orient themselves in three directions according to the hexagonal crystal structure of the mineral--star corundums have six legs or rays.

So when is a gemstone "flaw" a flaw? According to Koivula, an inclusion in a gemstone is never a flaw--in fact, stones without inclusions are the ones with "problems." And when enough inclusions get together to create phenomena such as aventurescence, chatoyancy and asterism, even the most inclusion-illiterate layperson would agree with him.

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