Stars, Stripes, & Spangles

Gemstone flaws, or inclusions, make for "phenomenal" special effects.

One person's flaw can be another person's asset. For example, many people with large noses would consider plastic surgery. Comedian Jimmy Durante made his "schnoz" his trademark. Niccoló 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, gemstone inclusions can be assets. Inclusions can help separate genuine from imitation (gas bubbles are not found in diamonds), distinguish a particular gemstone species ("lily pad" fractures indicate peridot), and even identify an individual gemstone (one reason why some jewelers provide a diagram of a gem's inclusions on their customers' appraisals).

PHENOMENAL FLAWS. 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 the average person 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. In a previous issue of *Lapidary Journal* ("Playful Color," June 1992), we took a look at phenomena derived from a gemstone's structure. But phenomena such as aventurescence, chatoyancy, and asterism appear when light strikes the inclusions in a mineral.

Broadly speaking, inclusions are foreign substances or growth characteristics inside a mineral. That includes (no pun intended) solids, such as crystals, needles (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 will explore are needles and flat, platelike 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 when there is 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 its molecules (which are clusters of atoms) are farther apart than they are at surface temperatures. Molecules of another type 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 into the relatively "open" areas in the host mineral's crystal structure along crystal planes.

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

Exsolution may create long fine crystals we describe as needles, or needlelike 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. A few 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.

AVENTURESCENCE. If you have ever visited any of the innumerable tourist areas across the U.S., 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 any other jewelry item. Goldstone, so the story goes, was discovered/invented accidentally by a clumsy Italian glassmaker centuries ago, when he knocked a pot of copper filings into a vat of

BELOW: Aventurescence in sunstone is caused by copper inclusions. Photo courtesy Ponderosa Mine. OPPOSITE PAGE, TOP: Delicate needlelike inclusions in chrysoberyl create a sharp cat's-eye and a silky sheen. Photo: Bart Curren/ICA. OPPOSITE PAGE, BOTTOM: In corundums such as this star sapphire, included needles orient themselves in three directions, creating a six-pointed star. Photo: Bart Curren/ICA.

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 sunstone (a type of feldspar) and aventurine quartz. In aventurine quartz, named for the phenomenon, flat crystals of mica, fuchsite (chromian 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 chromian 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.

THE CAT'S-EYE EFFECT, or *chatoyancy*, in a gemstone is caused by the reflection of light from numerous needlelike inclusions that may be solid crystals or 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 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 a 90° angle to the direction of the eye, just as the threads on a spool are perpendicular to the length of the spool. Because cat's-eyes 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.

Faceted sunstone from the Ponderosa mine in Oregon exhibits aventurescence and ranges in color from green to red. Photo © Tino Hammid, courtesy Ponderosa mine.

Many minerals can be cut to produce cat's-eyes: beryl, apatite, scapolite, tourmaline, quartz. But the winner, hands down, is chrysoberyl, 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 chrysoberyl cat's-eye are usually described as hollow growth tubes. However, John Koivula, chief gemologist at the Gemological Institute of America who bimonthly contributes "Inclusion of the Month" to *Lapidary Journal*, 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 but is best known in the corundums, especially ruby, blue sapphire, and black star sapphire. Perhaps the next best known for asterism are the star garnets.

In garnets, which form in the cubic crystal system, needles (often ilmenite) created by exsolution usually orient themselves in two directions, creating a four-rayed star. In corundum, needlelike inclusions (often rutile) orient themselves in three directions, reflecting 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. And when enough inclusions get together to create phenomena such as aventurescence, chatoyancy, and asterism, even the most inclusion-illiterate person would agree with him. ◆