A CLASSIFICATION METHOD FOR OPTICAL PHENOMENA OF CAT'S-EYES AND STARS IN MINERALS

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In gemstones, needle-like inclusions originate by crystallization of exsolved impurities which occupy structurally favourable specific crystallographic directions in the host mineral during cooling. Countless sub-microscopic needle inclusions near the surface of a cabochon-cut gemstone scatters and reflects light and forms an image that can be described as an optical-loop called a Cat's-eye. Two or more optical-loops cross each other and form a star effect or a network of stars in gemstones. Cat's-eyes and formation of stars and star networks are phenomena that are least explored areas in gemmology. Objective of this study is to develop a *classification method* of cat's-eye and star phenomena applicable to all gem minerals, revealing the effects in profound detail.

The study introduces quantitative and qualitative classifications to aid systematic study of cat's-eyes and stars. The quantitative approach (a) reduced the gamut of least explored cat's-eyes and stars into mere eighty nine types, a stereogram and a code visually illustrating complex star-networks analytically and the stereogram enabling the decoding of codes, (b) surfaced many missing links of cat's-eyes and stars laying a platform for new discoveries like sinhalite cat's-eye. The qualitative comparison scale portrays the quality of a cat's-eye/star from a commercial standpoint and determines the subjective value addition of the stone.

Both quantitative and qualitative research methodology was utilised to devise the classifications. Hypothesis test was carried out from observational study of needle inclusions including those given in previous literature. The result is significant that needles orient *parallel to each other* and *parallel to symmetry-axes-of-rotation of the host* crystal and form the optical-loops perpendicular to those even in rough gemstones. In a fashioned cabochon (sphere) an optical-loop moulds into a circular loop-plane, and hovers above the surface of the stone at a specific distance. This *hovering-distance* (d) is determined by the Wuthrich's equation $d = r/2(n-1)$ mm which relates to the radius of the sphere (r) and the host refractive index (n). Several symmetry-axes-of-rotation produce angled loop-planes which crisscross to form a star-network. To better understand the effect, the study utilized the relation of cat's-eye and star phenomena to the host crystal symmetry. The quantitative model developed here used this relation and incorporated the loop-plane as an *extra symmetry element* in the host *stereogram.* Model's *parameter* is *the formation of loop-planes perpendicular to symmetry-axes-of-rotation* and the *variable* is the component symmetry-axes-of-rotation, one hundred and six in total within the *thirty two symmetry classes.* The symmetry-axes-of-rotation are categorized into *stand-alones* (e.g. A_6), *sets* (e.g. $6A_2$), and *combinations* (e.g. A_42A_2, $6A_24A_33A_4$). The stand-alones produce *twenty seven* cat's-eyes, and both the sets and combinations yield *sixty two* star-networks, which is an exhaustive number for entire range of minerals. The total of eighty nine cat's-eye and star effects has been uniquely identified and a code has been developed to document and classify each one of those on the basis of component symmetry-axes-of-rotation producing the effect. Thus, a four-level and four/eight/twelve-digit code has been proposed in the classification.

Many gemstone examples were fitted into the coded classification and this included speculations. However, Sri Lankan star sapphire showed some inconsistency and additional data had to be gathered to improve it. Certain twin crystals display symmetries which deviate from their simple crystals and the new classification scheme is consistent with such compound crystals too. New scheme was also applied to star sapphires showing *polyasterism* to uncover the details of displaced sections of those crystals produced by deformation. The classification was finally applied on man-made fibre-optic cat's-eye material (amorphous) to learn the commercial manufacture of the star stones. A qualitative-model was developed to *compare* qualities of cat's-eye/star phenomena. The *parameter* is the hovering distance *d* of the phenomena whilst keeping constant the radius (r) of the stones under comparison. *Subjective variables* were the three quality factors of the comparing phenomena - *intensity*, *definition* and *colour.* To represent qualities of entire range of known phenomena a sample of twenty eight cat's-eye/star species were selected with radius r = 5mm. The quality factors of seven commercially accepted species were benchmarked and the benchmarks were utilized to develop a *comparison scale.* Comparison scale demonstrates relative position of a given cat's-eye/star with respect to a benchmark.