Origin of the Cat's-eye Effect in Heat-Treated Zircons from Sir Lanka

H.A. Hänni & M. Weibel
Zürich

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ABSTRACT

After undergoing heat-treatment, certain zircons from Sir Lanka exhibit a cat's-eye effect. The oriented inclusions which promote the chatoyancy are very fine fissures, crystallographically oriented parallel to the c-axis, and which apparently lie in the planes {100} and {010}. Prismatic crystals of about 1 micron length were found in the centre of the disc-shaped fissures (diameter about 15 microns). The Ca-content and the amorphous nature of these crystals indicate that they are thermally decomposed apatite.

INTRODUCTION

In the last five years, the cat's-eye effect in zircons has been noted on several occasions. Fryer (1983)[1] originally described grey-green and brownish-yellow stones with long, needle-like inclusions. Later, he described greyish and orange-brownish stones with flake-like inclusions (Fryer, 1985)[2]. Müllermeister (1985)[3] discussed yellowish zircon cat's-eyes with acicular particles exhibiting a bluish lustrous light effect. Reference should be made to the paper of Wüthrich & Weibel (1981)[4] for the theoretical explanation of comparable light effects.

The question which interests us is the type of oriented inclusions in the zircons which produce this effect (Fig. 1). A number of persons have claimed that the zircon cat's-eyes from Sri Lanka, possessing the bright light sheen, only acquire the effect after heat-treatment (Gübelin, 1988)[5]. On the other hand, non-heat-treated zircons apparently occur exhibiting a cat's-eye effect although with a less pronounced effect (Ito, 1987).[6]

*Dr. H.A. Hänni, Swiss Foundation for the Research of Gemstones (SSEF), Zürich.
Prof. Dr. M. Weibel, Institute for Crystallography and Petrography, Federal Institute of Technology (ETHZ), CH-8092 Zürich, Switzerland.

ANALYTICAL PROCEDURE

The material studied was examined using the optical microscope (up to 70x magnification), and the electron microscope. The zircon and inclusions were analysed by means of the Scanning Electron Microscope (SEM) with an energy dispersive analysis system (EDX). Transmission electron microscope (TEM) studies were carried out on an oriented thin section which had been thinned by ion-etching. Transmission photographs and electron beam diffraction patterns were taken at chosen locations. Electron diffraction results defined the orientation of the zircon crystal lattice to the cabochon. An attempt was also made to determine the crystalline character and identity of the inclusions. The qualitative chemical composition of the inclusions was investigated by EDX to the carbon-coated sample.

RESULTS

Under the optical microscope, the very numerous, minute and parallel-oriented disclets or "flakes" are conspicuous. They can easily be made visible when reflecting the light of a fibre optics illumination system. The disclets are oriented in either one or two possible orientations, both of which are parallel to the c-axis (Fig. 2). It is suspected that these are the two cleavage directions perpendicular to the basal plane of zircon. Thus, on the zircon studied by the authors and dependent on the orientation of the stone, one of the two systems of disclets can be brought to reflect. The cabochon basal plane must merely lie parallel to the c-axis or one of the prism faces, respectively. The light line will then run perpendicular to the c-axis over the cabochon's surface.

The EDX-spectrum exhibits the elements to be expected in high-zircons, namely Si, Zr and minor Hf (Fig. 3). The electron beam diffraction pattern reveals the monocrystalline nature of the zircon matrix. It also shows that in correctly cut attractive stones, the c-axis of the zircon lies in the basal plane of the cabochon, and in fact at right-angles to the light line of the cat's-eyes. A TEM picture taken on the {010} plane reveals the extremely fine fissures, 15-20 microns in length, which exit at right-angles to the plane. In the centre of these fissures in {010}, with favourable position of the section, crystal-like inclusions can be seen (Figs. 4&5), also parallel to the c-axis. They exhibit a slightly rounded prismatic habit and are about 1 micron in length.

The fact that we were not able to obtain electron diffraction patterns from the crystal-like inclusions indicates that they are now amorphous. The possibility of these being gas/liquid inclusions would not seem to be very likely, as the EDX spectrum established the presence of an element (Ca) not present in the zircon matrix. We assume that these minute inclusions were originally apatite. The main phosphorus line (Kα at 2.0 KeV) in the EDX spectrum which, together with Ca would indicate apatite, would be hidden by the strong Zr Lα line from the zircon matrix (Fig. 3).

It remains conjecture therefore that these inclusions are of apatite origin. Future studies on untreated material should resolve the identification of the inclusions.

The presence of apatite inclusions in zircon is justifiable on genetic considerations, since both minerals can be formed as early depositions in magmatic rocks. Syngenetic formation of apatite with zircon would seem to be plausible in the case of the Sri Lankan material studied by the authors.

The relative brightness of the fissure edges in figure 4 can be explained by the increased emission of electrons from the respective surface structure. Surprisingly, the fissure edges jut out after treatment by ionic etching, and this suggests slightly different properties from those of the normal zircon matrix.

The stabilisation of the fissure edges and the amorphous character of the inclusions seem to indicate that thermal treatment has been carried out on the material.

DISCUSSION

Two types of zircons exhibiting cat's-eyes effect would appear to occur in Sri Lanka. One of the types contains needle-like particles, traces of U and Th, and has a density of about 4.62 g/cm³ (high zircon) (Müllermeister, 1985)[3].

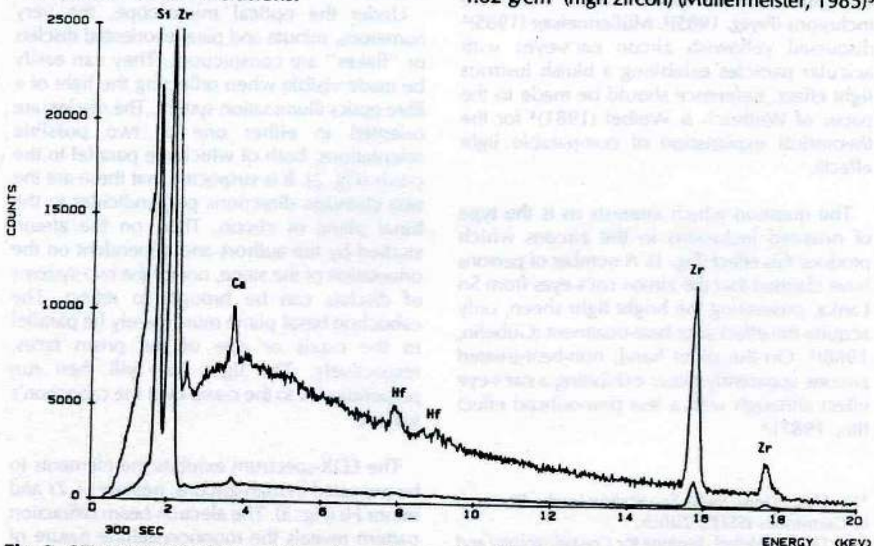

Fig. 3. SEM-EDX spectrum of the zircon host mineral and one of the minute crystal-shaped inclusions, The Ca signal stems from the inclusion. The upper spectrum is shown at increased sensitivity.

The second type is endowed with numerous and very fine parallel fissures which lie in the cleavage direction {100}, {010} respectively. The density of these zircons lie between 4.67 and 4.77 g/cm³ (high zircon).

Previous authors have recognised chatoyancy as being the result of the presence of multitudes of fine parallel fissures, e.g. in corundum (Schmetzer & Kiefert, 1987)[7], and in Kyanite (Ito, 1987)[6].

Although two systems of inclusions producing chatoyancy were found in the zircons examined, the stones are not suitable for the production of star-stones. This is because the fissure-planes lie at right-angles to each other, so that at any one time, only one of the two systems can be brought into a favourable reflection position. The traces of the other system are not capable of reflection at the same position.

It would seem that the fisssures were formed due to strain encountered during heating or cooling around the crystal-shaped inclusions. Disc-like strain cracks belong to the well-known inclusions types in the zircons from Sir Lanka (Gübelin & Koivula, 1986)[8], and these are also oriented parallel in untreated stones, although are usually larger and less numerous. Their origin is often regarded as a result of a

Fig. 1. Zircon cat's-eyes from Sri Lanka. Diameter of the biggest stone is 8mm.

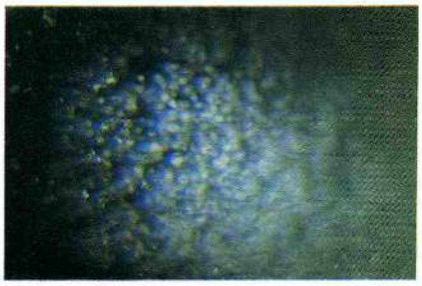

Fig. 2. Microphotograph of the disc-like fissures in two systems. The one system in reflection position (light ovals), and the exit traces of the fissures representing the other system, visible as short streaks.

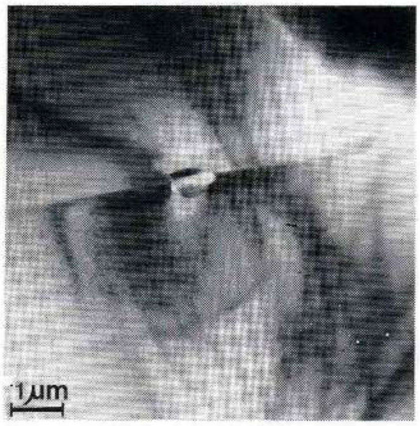

Fig. 4. TEM picture of a fissure with crystal-like inclusion. The fissure is virtually at right-angles to the plane of the figure.

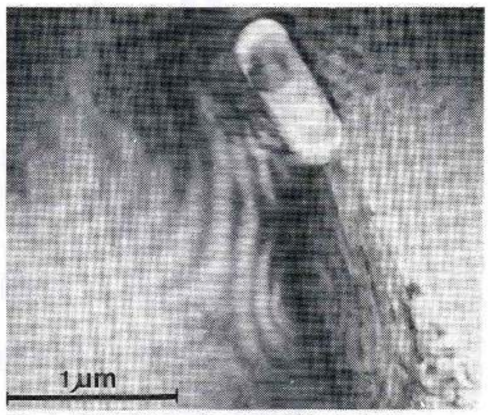

Fig. 5. TEM picture of a crystal-like inclusion, which lies in a flat fissure (perpendicular to that of Fig. 4). The inhomogeneous nature of the inclusion is conspicuous.

disintegration process and volume changes due to the influence of radioactive auto-irradiation (metamictisation). Quantitative data on radioactive elements in zircons from Sir Lanka were presented by Rupasinghe (1985)[9]

Regarding the possibility of treating zircon, such information is given by Nassau (1984)[10], although he only deals with colour changes. The temperatures employed lie in the region 1000 to 1400°C, adequate for the thermal decomposition of apatite. Due to the condition of the decomposed apatite (?) inclusion in the heat-treated zircon cat's-eyes, we expect a similarly high temperature to have been employed.

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