Colored Varieties of Quartz Arising From Inclusions. C. Ma, J. S. Goreva, and G.R. Rossman[1], Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, USA, [1]grr@gps.caltech.edu

Introduction: Research into the origin of color of common varieties of quartz has shown that many long-held beliefs regarding the origin of the colored varieties are incorrect. In particular, the widely stated role of rutile inclusions in the coloration of rose and blue quartz must now be re-evaluated on the basis of new studies.

Rose Quartz: Spectroscopic studies have shown that the color of rose quartz originates from fibrous inclusions within the quartz [1]. Samples of rose quartz from numerous localities were dissolved in acid and the insoluble residues were purified and examined by microscopic, spectroscopic and analytical methods. The fibers are an aluminoborosilicate that is related to dumortierite. Borate is confirmed by infrared and EELS spectra and by ICP-MS analysis. Infrared spectra demonstrate that it is present as BO_3^{3-}. OH is confirmed by infrared spectra and the major components are analyzed by EDS analysis in the TEM.

The structure of the fibers was solved using high-resolution TEM images, cell constants and chemical analysis from the TEM. The fibers have a unique electron diffraction pattern that is related to dumortierite by a superstructure relationship in which the a and b axes are doubled and cations are preferentially ordered on Al sites.

Laboratory experiments have demonstrated that, depending on the Fe and Ti content of the fibers, it is possible to cycle the color of the fibers from rose to colorless to blue. Corresponding color variations are found in nature.

In addition to its occurrence in rose quartz, this phase has now been found co-existing with dumortierite at a classical dumortierite locality.

Blue Quartz: The properties of blue quartz suggest that the color is associated with scattering from a second phase included in the quartz. For many years, the second phase was assumed to be rutile [2]. TEM studies of blue quartz are now available from 3 localities. A source of the scattering was identified in a TEM investigation of blue quartz phenocrysts from the Llano Uplift, Texas [3]. Inclusions in the quartz are rounded ilmenite grains averaging ~0.06 µm in diameter with a density of about $125/\mu m^3$ and that the depth of color correlated with the density of the inclusions. A sub-micrometer iron-titanium oxide (presumed to be ilmenite) was found in blue quartz from the Roseland district, Virginia, and was presumed to be the cause of the color [4].

We examined blue quartz from Piney River, Nelson, Va. Bright field images and EDS analyses revealed that both ilmenite and rutile inclusions are present in this blue quartz. The more abundant rounded ilmenite grains are about 100 - 500 nm in diameter compared to the rod-shaped 30-50 nm x 300 nm rutile crystals.

The combined evidence from the three studies indicates that sub-micrometer inclusions of ilmenite are a common cause of color in blue quartz.

References: [1] Goreva J. S. et al (2001) *Amer. Mineral*., in press. [2] Vultée and Lietz (1956) *N. Jb. Min. Monat*. 3, 49-58. [3] Zolensky et al. (1988) *Amer. Mineral*. 73, 313-323. [4] Nord, cited in Herz and Force (1984) *Geol. Soc. Amer. Spec. Paper* 194, 187-200.

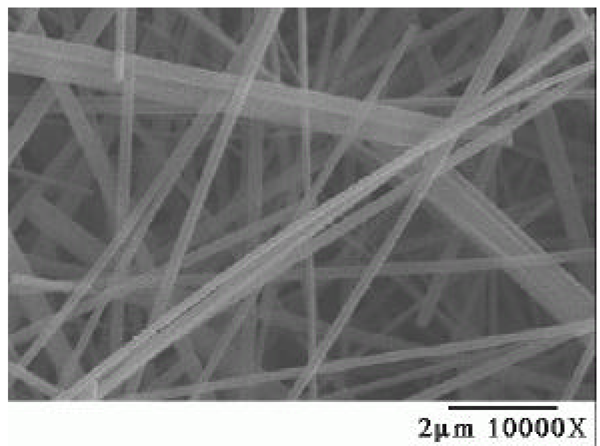

Figure 1. Aluminoborosilicate fibers extracted from rose quartz.

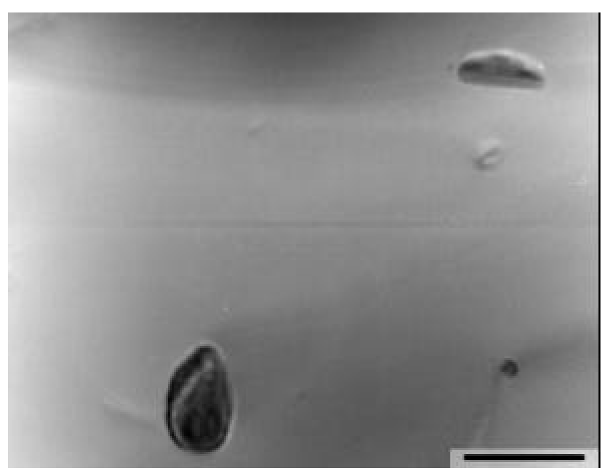

Figure 2. Ilmenite inclusions in blue quartz. The bar in the lower right is 300 nm long.