

Nanomineralogy of gemstones: From genesis to discovery

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Nanomineralogy is the study of Earth and planetary materials at nanoscales, focused on characterizing nanostructures (like inclusions, exsolution, zonation, coatings, pores) in minerals and rocks, and revealing nanominerals and nanoparticles [1]. With advanced high-resolution analytical scanning electron microscope, we are now capable to characterize solid materials easier and faster down to nanometer-scales. During our nanomineralogy investigation of gemstones, nanostructures are being discovered in many common gems, which cause color and other optical effects, and provide clues to genesis. Presented here are a few colorful projects demonstrating how nanomineralogy works and plays a unique role in gemstone and geomaterial research.

Rose quartz contains nanofibers of a dumortierite-related phase that is pink, which is the true cause of rose color and optical star effects [2,3]. Sub-micrometer inclusions of ilmenite are the cause of color in blue quartz.

Why is obsidian black? Because most obsidians contain nanostructures of magnetite. 'Fire' obsidian, a variety of obsidian from Oregon, has thin layers showing various colors. The layers, 300 to 700 nm thick, consist of concentrated nanocrystals of magnetite, giving rise to brilliant colors in reflection due to thin-film interference [4]. Whereas 'rainbow' obsidian from Mexico contains oriented nanorods of hedenbergite, which cause the rainbow effects via thin-film interference [5].

During a study of benitoite, the state gemstone of California, new mineral bariooperovskite (BaTiO_3) and two more new barium titanate minerals BaTi_2O_5 and BaTi_3O_7 were discovered to occur in a tubular inclusion within one benitoite crystal [6].

[1] Ma (2008) *Eos Trans. AGU*, 89, abs MR12A-01.

[2] Goreva *et al.* (2001) *American Mineralogist*, 86, 466-472.

[3] Ma *et al.* (2002) *American Mineralogist*, 87, 269-276.

[4] Ma *et al.* (2007) *Canadian Mineralogist*, 45, 551-557.

[5] Ma *et al.* (2001) *Canadian Mineralogist*, 39, 57-71.

[6] Ma and Rossman (2008) *American Mineralogist*, 93, 154-157.