

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 nanofeatures (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, nanofeatures 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 nano-inclusions 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 barioperovskite (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.

Granite compositions: Source vs. process, revisited. An isotopic traverse across SE Australia

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Granite compositions are determined by source characteristics, by details of melting, melt extraction and transport through the crust, by magma mixing and assimilation at various scales and depths, and by magma chamber processes. The importance of each factor is often difficult to ascertain. We examine this issue using Sr-Nd-O isotope data for 430-370 Ma granites across the Paleozoic Lachlan Orogen (LO), SE Australia.

S-types granites in the eastern LO show strong isotopic links with Lower Paleozoic low- ϵ_{Nd} meta-turbidites which dominate the mid crust. Further west, geophysical data suggest the presence of a greenstone-dominated, lower/mid-crustal Neoproterozoic block with a thickness of 25 km above Moho, the Selwyn Block. S-type granites in this area have higher ϵ_{Nd} , $\delta^{18}\text{O}$ and lower $^{87}\text{Sr}/^{86}\text{Sr}$ than those in the eastern LO, and links to the meta-turbidites – present above the block – are weak. In the far western LO where the mid crust comprises thick, imbricated Cambrian metabasalts overlain by meta-turbidites, S-types show the widest isotopic range (ϵ_{Nd} -2 to -9), consistent with links to both metabasalts and turbidites.

I-type granites in the eastern LO show strong Sr-Nd isotope covariation; their large range in ϵ_{Nd} (+6 to -8) could reflect source rock heterogeneity (e.g. Cambrian greenstones underlying the meta-turbidites have a similar isotopic range), syn-magmatic mixing (crustal assimilation), or both. I-types in the western part of the orogen are isotopically diverse, with distinct trends in Sr-Nd-O isotope plots in the various structural zones, but links to known lower crustal features appear to be weaker than for the S-types.

The data from this example suggest that heterogeneity in source (isotopic) compositions is transferred to S-type granite/volcanic compositions with little disturbance by post-melting processes, at least at an orogen-wide scale. I-type petrogenesis appears to be more complex and probably involves mixing processes (mixed sources, syn-magmatic mixing).