COLOR BLIND

I want to call your attention to a problem with the use of colored figures in professional papers and oral presentations. The difficulty is the inability of many folks to distinguish some colors or, in rare cases, any colors. Recent examples are the well-written and informative papers in *Elements* by Filippelli and others (December 2012) and Yoshida and Takahashi (June 2012). I am unable to distinguish between the various colored patterns in some of their figures, being red-green color blind. I know from many years of experience that those with "normal" color vision are unaware of this difficulty or pay it little consideration, just as those of us who are right-handed pay little heed to some issues associated with the sinistral.

Fortunately, with color blindness, there often are simple solutions to the problem. For example, rather than using O and O to distinguish apples from oranges, patterns with or without colors, such as ⊗ and O, will do nicely. This also eliminates the need for making colored copies. Color blindness in many cases is not a significant encumbrance, but it is fairly common, certainly common enough that authors of technical papers should consider it in their presentations.

The first written report of color blindness appears to have been by chemist/physicist John Dalton, who, in 1794, reported on this phenomenon in himself and his brother (see Dickinson et al. 1996). John Rosenfeld, my colleague at UCLA, is a world-class petrologist and optical mineralogist; like me, he is red-green color blind. Perhaps 10% of human males are so "endowed" (e.g. Dawkins 2004, page 154); females show this trait far less commonly, because *both* X chromosomes must be affected to result in color blindness. Curiously, most humans, birds, fish, and reptiles and some marsupials have superior color vision, whereas most mammals do not. Some groups of humans, including the Inuit, appear to have nearly no color blindness, whereas in some populations, a significant percentage of men *and* women are completely color blind (achromatopes), as entertainingly documented by Oliver Sacks (1998) in *The Island of the Color Blind*.

A mineral birefringence chart calling attention to color blindness was developed by William Peck and published in the *Journal of Geoscience Education* in 2007 (Fig. 1). I am unable to distinguish between the two diagrams, and John Rosenfeld notes a barely perceptible difference.

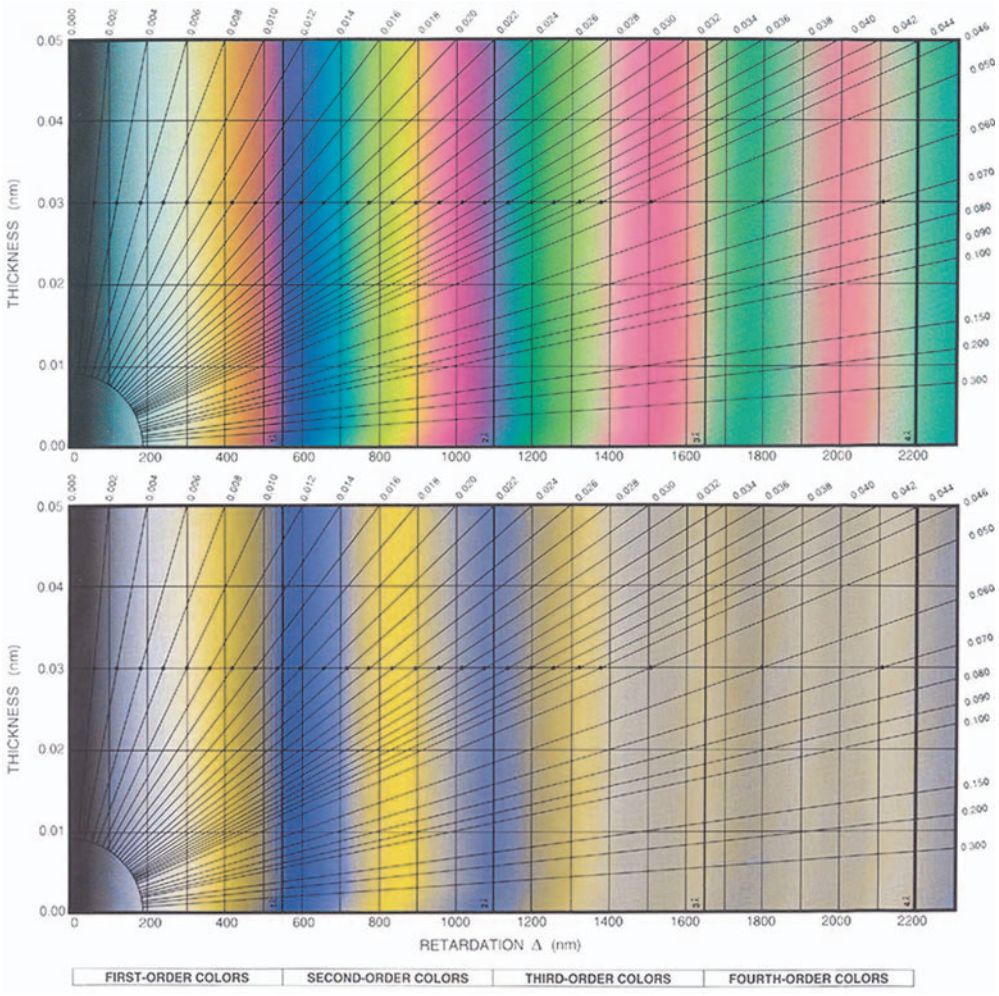

Figure 1 (**Top**) The Michel-Lévy interference color chart for optical mineralogy (**Bottom**) The same chart as seen with red/green color blindness (deuteranope). Mineralogy/petrology instructors should be aware that students with color blindness will have trouble with aspects of birefringence and pleochroism. The Michel-Lévy chart is from *Optical Crystallography* by F. Donald Bloss (1999, Mineralogical Society of America Monograph 5, 239 pages). The deuteranope simulation was created using Vischeck.com, which contains a number of good resources on color blindness. Composite image reproduced courtesy of William H. Peck (Colgate University)

Websites are now available to assist the color blind with images on computers and smart phones. Gene therapy holds promise of eliminating red-green color blindness in humans, as it has done in squirrel monkeys (Mancuso et al. 2009). Perhaps this is not as advantageous as it might appear. During my years as a flight engineer on B-36 bombers in the US Air Force, we were told that color-blind airmen, as well as soldiers, were useful for detecting camouflage. This non-color acuity is now well documented for many situations. We all have a role.

Art Montana
University of California, Los Angeles

REFERENCES

Dawkins R (2004) The Ancestor's Tale. Houghton Mifflin Co, Boston, pp 145-155

Dickinson C, Murray I, Carden D (eds) (1996) John Dalton's Colour Vision Legacy. Taylor & Francis, London, 738 pp

Filippelli GM, Morrison D, Cicchella D (2012) Urban geochemistry and human health. Elements 8: 439-444

Mancuso K, Hauswirth W, Qiuhong L, Connor TB, Kuchenbecker JA, Mauch MC, Neitz J, Neitz M (2009) Gene therapy for red-green colour blindness in adult primates. Nature 461: 784-787

Sacks O (1998) The Island of the Color Blind. Vintage Books, New York, 93 pp

Yoshida N, Takahashi Y (2012) Land-surface contamination by radionuclides from the Fukushima Daiichi nuclear power plant accident. Elements 8: 201-206