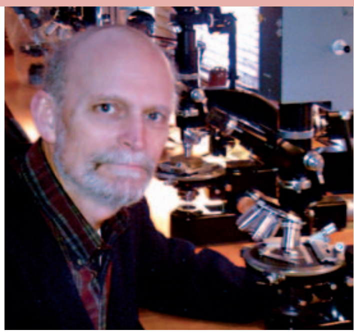
Editor's note: Dan Kile contacted us over a year ago with an offer to write an article on the importance of optical microscopy as an analytical technique. In light of the extensive discussion of the topic on the MSA listserv recently, Dan's thoughts seem very timely.

Polarized Light Microscopy in Geoscience Education: Relevant or Obsolete?



For more than 100 years, optical mineralogy has been a staple of the geosciences curriculum. In the past, it was the *only* means of identification for certain minerals, and a high level of proficiency was required. At present, however, most universities have reduced the optical mineralogy component of the program, either by eliminating it entirely, or by integrating it with other courses. Consequently, microscopy instruction has evolved towards "cookbook" styles of teaching, and many students can graduate with a geosciences degree without ever having used a polarized light microscope (PLM).

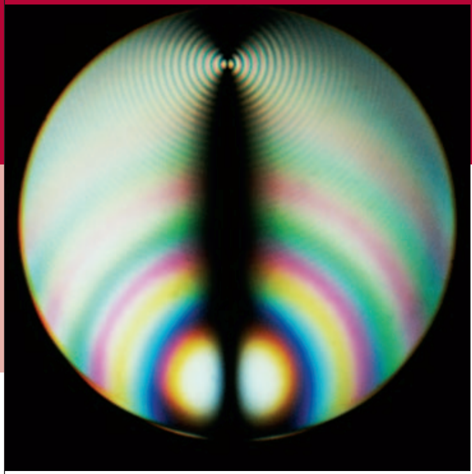
The reasons for this decline are varied. First, X-ray diffraction (XRD), scanning electron microscopy (SEM), and electron microprobe methods have largely supplanted (not replaced!) optical methods. This trend parallels an increasing reliance on computers to provide ready answers for a given set of analytical data. A number of factors have conspired to create this situation. In the case of XRD, for example, a technician can be trained to prepare samples, operate the instrument, and generate a list of mineral phases present in about an hour. In contrast, well-grounded training in optical mineralogy takes a substantial investment of time and considerable practice. Second, and perhaps most importantly, an evolving curriculum (whereby new course requirements such as remote sensing, geophysics, aqueous geochemistry, and fluid flow have been added to accommodate a changing science) mandates that something has to give in the degree program. Third and less obvious is the diminished likelihood of competing successfully for NSF funding for studies based on a methodology deemed by some to be anachronistic.

As a result, the capability for PLM work in both collegiate and industrial sectors is drastically reduced. With each retirement of a classically trained crystallographer or petrologist, the knowledge base of mineral optics declines. One wonders if we will reach a point of no return, with no one able to pass on skills long since forgotten. Because teachers have a propensity to teach as they have been taught, new faculty will be less likely to incorporate optical methods into a curriculum amidst the press of other demands. Moreover, in a self-fulfilling prophecy, decreased demand for PLM equipment is leading to a decline in the commercial availability of optical apparatus and teaching aids.

I would argue that despite the introduction of microbeam and XRD technology, polarized light microscopy remains a versatile, efficient, and necessary technique for the identification of crystalline materials, not only in the geological sciences, but also in materials sciences, forensics, pharmaceuticals, environmental sciences, archeology, and chemistry.

Why *is* PLM still a critical component of an undergraduate science degree?

- PLM provides a range of sample information that is not equaled by other methods of analysis. Pleochroism, birefringence, dispersion, crystal textures, intergrowths, polymorphic phases, and dispersion are among the characteristics that are best assessed by PLM.



An unusual interference figure of a twinned diopside crystal, from an oriented section made in ca. 1900 by the firm Steeg and Reuter. Such preparations, used to illustrate properties of retardation and birefringence as related to isochromes, were commonly used in earlier years and are now seldom seen.

- Given the great expense of a $200,000 X-ray diffractometer compared to a $10,000 polarizing light microscope, it is apparent that a PLM is far more cost effective. Moreover, most graduates out in the working world will find that there is no microprobe down the corridor, and contracting analytical work for XRD and microbeam analysis can be both expensive and time consuming. Conversely, training in PLM will permit graduates to expeditiously and economically answer many real-world problems.
- Training in microscopy hones the often-overlooked yet important skills of careful observation, data recording, and three-dimensional visualization; combined with careful reasoning it engenders critical abilities in cognitive learning that few other disciplines can provide. Computer analysis cannot replace human observation and judgment.
- Few other subjects offer the integration of so many fields of science as does optical mineralogy, e.g. physics, chemistry, mineralogy, and geology.

One must ask what will be the consequences if PLM and mineral optics are shortchanged in the curriculum? The use of immersion methods, universal stage, and rotating compensators are becoming lost arts, and the level of understanding of mineralogically important topics, such as dispersion and its relation to crystal symmetry, is declining each year. Immersion preparations can be especially important. For example, they allow extraction of far more information from a given sample than can be seen in a standard thin section, and they afford, by virtue of thicker grains, a much better visualization, and hence understanding, of optical properties as related to crystallographic orientation. Yet few colleges offer this instruction, largely because such knowledge has not been passed on to the present generation of instructors. The universal stage provides unique capabilities not replicated by any other instrument, but the ability to use it will soon fade with the gradual disappearance of the equipment and the knowledge of its operation.

With the elimination of a full-semester course in optical mineralogy at most institutions, many approaches have integrated optics with classes in mineralogy, petrology, or instrumental analysis. Is this trend in the best interests of the students and the science? In my opinion, an abbreviated format does not permit introduction of important concepts such as the indicatrix, conoscopy, relief, anomalous interference colors, dispersion, or immersion methods. Moreover, simple cookbook methods (e.g. identifying a mineral in thin section as quartz because "it looks like quartz") are mostly inadequate; without a firm understanding of the fundamentals, mistakes are inevitable. Competency can only be attained from a thorough course of instruction; short courses, video instruction, and on-line classes, while serving an important purpose, are no substitute for rigorous hands-on training in the presence of an instructor. After all, how comfortable would one be flying in a 747 piloted by an individual whose training was limited to reading an owner's manual and practice on a flight simulator?

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Meet the Authors

Alex N. Halliday was recently appointed to the Chair of Geochemistry at the University of Oxford where he moved from ETH Zurich. In the past he has engaged in a broad range of isotope geochemistry research, in particular in silicic magmatism, crustal fluid flow, lower crustal processes and mantle geochemistry. More recently however his interests have broadened to the origin and early differentiation of the terrestrial planets and large-scale surface processes such as ocean circulation. An underlying research theme has been the development and use of new isotopic methods. He is involved in a wide range of scientific organizations.

Photo: D. Jalufka

Christian Koeberl is a professor of geo- and cosmochemistry at the Department of Geological Sciences, University of Vienna, Austria. He studied chemistry and astronomy at the Technical University of Vienna and the universities of Vienna and Graz, where he finished his PhD in 1983 in cosmochemistry. In the 1980s and 1990s he was a visiting scientist at the Lunar and Planetary Institute, Houston, and at the Carnegie Institution of Washington. For the past 20 years the study of impact craters and processes has been one of his main research interests. He has published about 280 peer-reviewed papers and written or edited nine books.

Allen Nutman's interest in early Archean geology has spanned three decades, starting with his late 1970s PhD work (at the University of Exeter, UK) on rocks of Archean age in West Greenland. Since the late 1980s he has been based primarily at the Australian National University, where he works at the SHRIMP facility in the Research School of Earth Sciences. He has worked extensively on the early Archean rocks of West Greenland and Western Australia, and has also undertaken research on similarly old rocks from Labrador and China. His approach is to integrate field observations, mapping and geochemistry with zircon geochronology.

J. William Schopf is director of the Center for the Study of Evolution and the Origin of Life and member of the Department of Earth and Space Sciences at the University of California–Los Angeles. He received his undergraduate training in geology at Oberlin College and his PhD degree in biology from Harvard University. Author or editor of three prize-winning volumes on the early history of life, his prime research interest, Professor Schopf is a member of the National Academy of Sciences, the American Philosophical Society, and the American Academy of Arts and Sciences. Recipient of numerous medals and awards, he has twice been awarded a Guggenheim Fellowship.

John W. Valley, Charles R. Van Hise Professor of Geology at the University of Wisconsin–Madison, received his AB from Dartmouth College and PhD from the University of Michigan (1980). He maintains a mass spectrometer lab for stable isotope geochemistry and in 2005 installed a CAMECA IMS-1280 ion microprobe for in situ analysis of ultrasmall samples. His interests in the early Earth and in the thermal and fluid history of mountain belts span 30 years. Currently, he is president of the Mineralogical Society of America.

Kevin Zahnle is research scientist at NASA's Ames Research Center located in California's Silicon Valley. He attended McGill University and the University of Michigan. Then he moved to California. He has studied atmospheric chemistry, atmospheric escape processes, and asteroid and comet impacts on planets and satellites. Zahnle has contributed film reviews to *Nature* and has appeared on TV as Godzilla in NHK's "Miracle Planet II."

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Cutting back the role of optical mineralogy in the geosciences curriculum needs to be carefully reconsidered—especially by those departments contemplating elimination of the program altogether. Given the present state of affairs, however, it is unlikely that optical mineralogy will be reinstated to a full semester course of instruction. The best alternative is to integrate it as much as possible with the entire range of mineralogy, petrology, and analytical courses, rather than simply relegating optical work to a few lectures and laboratory sessions. This approach might be the best means of conveying the versatility of this powerful technique to future generations of geoscientists.

Daniel Kile
Scientist Emeritus,
U.S. Geological Survey

WATCH FOR OUR NEXT ISSUE

Glasses and Melts: Linking Geochemistry and Materials Science

GUEST EDITORS: Grant S. Henderson (University of Toronto), Georges Calas (IMPMC and Université de Paris 6 et 7), and Jonathan F. Stebbins (Stanford University)

Geological interest in studying melts stems from early recognition that melts play a fundamental role in determining the physical and chemical behaviour of magmas. However, due to the inherent difficulties associated with working at high temperatures, much of the geological research over the last 30 years has used quenched melts or glasses as proxies for melts themselves. The assumption that the structure of the glass resembles that of the melt has been found to be good, at least at the temperature where the melt transforms to a glass. We will review how glass research has contributed to our understanding of melt structure and the behaviour of magmas. Emphasis is placed on elucidating the links between our knowledge of the atomic structure of melts and the macroscopic behaviour of magmas such as rheology, diffusion, trace element partitioning and redox behaviour.

The structure of silicate glasses and melts
Grant S. Henderson, Georges Calas, Jonathan F. Stebbins

Geochemical aspects of melts: Volatiles and redox behaviour
Harald Behrens (University of Hannover)

Transport properties of magmas: Diffusion and rheology
Donald B. Dingwell (University of Munich)

Dynamics of magmatic systems
Bruce D. Marsh (Johns Hopkins University)

Geological glasses as Earth and industrial materials
Laurence Galoisy (Institut de minéralogie et de physique des milieux condensés and Université de Paris 6 et 7)