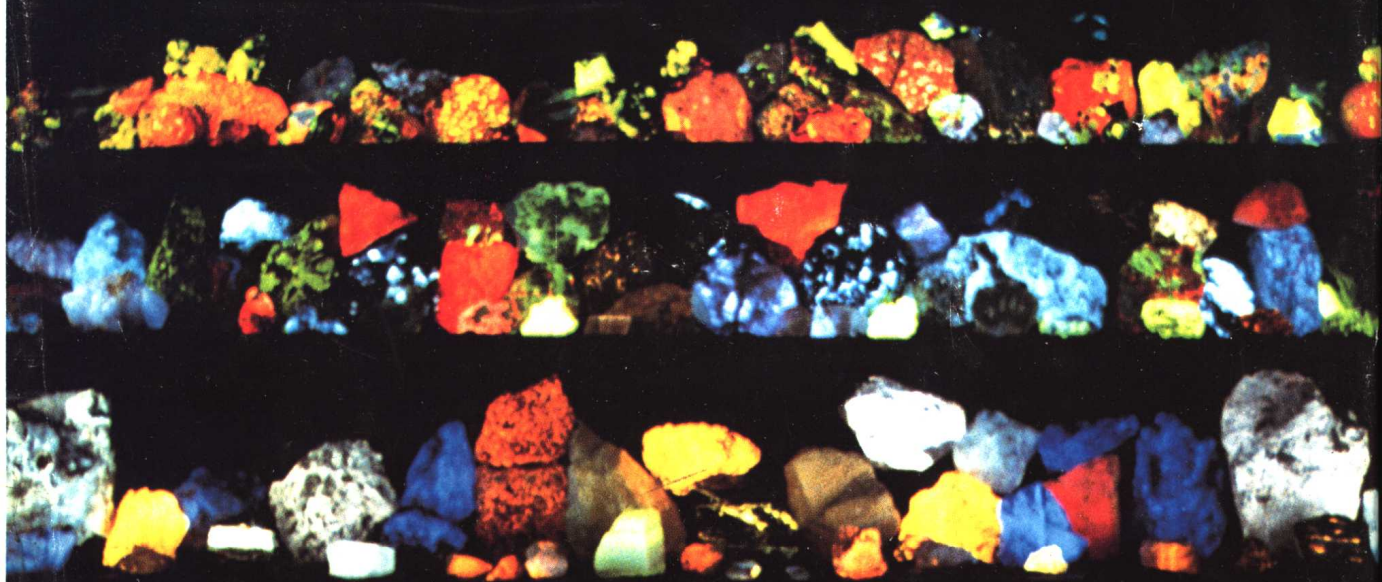


The Collector's BOOK of Fluorescent Minerals



Manuel Robbins

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Preface

Over the last several decades, the number of people who are actively involved in the hobby or science of mineral collecting has grown at an increasing pace. In response to the growing demand for information which this large and active group has created, a number of books have been published dealing with mineralogy. As a result, the reader now has a choice among mineral locality guides, field handbooks, photo collections, or books dedicated to the systematic description of minerals.

However, as interest in mineralogy has grown, as collectors have become increasingly knowledgeable and aware of mineralogy in its many facets, the need for more specialized information has also grown. Nowhere is this need greater than in the subject of the fluorescence of minerals. The number of collectors who now maintain a fluorescent collection is substantial, interest is constantly increasing, and manufacturers have recently responded by the introduction of new ultraviolet equipment with major improvements in utility and performance. Yet when the collector searches for any information on this subject, little will be found. He or she will seek in vain for the answers to questions which present themselves as interest in fluorescent minerals grows and matures. Which minerals fluoresce? Where are fluorescent minerals found? What makes a mineral fluoresce? Why does ultraviolet light produce fluorescence? What is an activator, and how does it contribute to fluorescence? On these matters, the available mineralogy books are largely silent.

These same questions inevitably arose as my own interest in fluorescent minerals developed. I have been a collector of Franklin minerals and, of course, I gathered as many of the fabulous fluorescent minerals of Franklin as could be obtained. Then, slowly at first, I began to recognize that fine fluorescent minerals could be found elsewhere and the scope of my collecting broadened. This required that I search for fluorescent minerals at mineral shows, in the shops of mineral dealers, and in the field, looking for fluorescent surprises from far off places. Time after time, I found them. Most of the fluorescent minerals found this way were surprises if only because so little has been written about fluorescent minerals that each find was a discovery, a revelation. As my collection grew, so did the notes which I kept. The notes described not only fluorescent minerals collected or purchased, but also those seen, those written about, or those described to me by fellow collectors. These provided a target list for future acquisition.

Soon enough, the question of the cause of fluorescence in minerals became important. Here a different type of search was required, a search through the technical books and journals which report the investigations of physicists and physical chemists into the causes of luminescence, which is simply fluorescence and phosphorescence in our terms. Discussions with scientists working in this field were also helpful and provided useful information.

Until that time, I had been motivated by my own interest and curiosity, but as time went on, as I talked with many other mineral collectors, it slowly became clear that there existed a widespread need for information on mineral fluorescence. To fill this void, a book would be required, and so, this book was written.

The book is addressed primarily to the mineral collector. The beginning collector should find here a guide and help to collection building. He or she will find information on the type of ultraviolet light to use, the minerals to look for, where to find them, and the way to organize the collection. It is likely that the advanced collector also may find here useful or interesting information beyond his or her present knowledge. If the beginning collector is aided, if the more advanced collector finds here the answers to some things he or she has been wondering about, I feel that this book will have fulfilled its purpose.

I have visited and collected minerals at a number of localities mentioned in this book. These visits have been particularly useful in preparing Chapter 5. In preparing that chapter, I also called upon a number of people who have provided help, especially by patiently answering a number of questions or reviewing material relating to the locality or mineral formations in which they specialize. I appreciate their help, and I want to thank Fred Totten of the Gouverneur Talc Company at Balmat, New York, and C. MacDonald Grout and Bill Lorraine, geologists of the St. Joe Resources Company, whose offices are also at Balmat, New York. Similarly, thanks are extended to John Baum, retired geologist of the New Jersey Zinc Company at Franklin, and Jim Minette of the U.S. Borax operation at Boron, California. Both Fred Divoto and Ruth Kirkby, dedicated collectors of Crestmore minerals, have also been helpful with regard to the geology and mineralogy of that remarkable location. At Searles Lake, Gail Moulton and Steve Mulqueen, geologists of the Kerr-McGee Company, extended every courtesy, and their help is acknowledged. Richard Gaines of Pottstown, Pennsylvania, also provided help for which I am grateful.

A number of these people also allowed me to examine under the ultraviolet light the office or reference collections which are maintained under their supervision and to make useful notes on the fluorescence of some minerals which I might not have had a chance to see

otherwise. Others helped in this way. Ewald Gerstmann of Franklin, New Jersey, permitted me to examine a number of specimens in the Gerstmann-SPEX collection of Franklin minerals. Dick Bostwick and Warren Miller allowed me to inspect their personal Franklin fluorescent collections. Tom Peters allowed me to examine the extensive collection of zeolite and other minerals in the Paterson Museum at Paterson, New Jersey. The courtesy and help of all of these people are acknowledged with thanks.

David Williams of the Center for Visual Science at the University of Rochester reviewed a number of questions relating to Chapter 9. His help is appreciated. Maria Crawford of Bryn Mawr College devoted substantial time on many occasions in order to identify a number of silicate minerals described in this book. I also want to thank Neil Yocum of the RCA Research Laboratories at Princeton, New Jersey. His years of experience in developing both phosphors and laser materials have given him deep insight into the nature of fluorescence and the activators involved. He has helped me on many occasions when some point in the technical literature was particularly unclear.

I also want to thank Tom Warren of Ultra-violet Products for recounting his experiences in Chapter 4. For that chapter, Dick Bostwick was kind enough to provide an account of his experiences in the Sterling mine. Don Newsome, first president of the Fluorescent Mineral Society, provided the graphs of the spectra of a number of fluorescent minerals which appear in Chapter 9. I extend thanks to them all.

Color photographs of a number of fluorescent minerals are provided as a means of illustrating the beauty and variety to be found among fluorescent minerals, and as an aid to identification. Most of these photographs are of specimens in the author's collection. These were photographed at $f/4.5$ on Kodachrome ASA 64 with time exposures ranging between 7 and 50 seconds. The minerals were illuminated by hand held ultraviolet lights at several inches distance. Other photographs are of specimens in other collections, and their owners were kind enough to furnish these photographs for use here. Tom Warren of Ultra-Violet Products furnished color pictures of specimens 27, 29, 50, 53, 55, and 56. Specimen 61 is in the Ray Vajdik collection. Specimens 39 and 60 are in the Charles Weed collection. Specimens 35, 63, and 64 are in the Dick Bostwick collection, and specimen 62 is in the Warren Miller collection. Thanks are extended to all for the use of these photographs.

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1

Background

Man is one of those few creatures who can see the world in color. Almost as far as we are able to trace the presence of man in history and prehistory, we find evidence that he has employed color to adorn his person and his surroundings. Tens of thousands of years ago, Cro-Magnon created cave paintings using the colors of minerals as pigments, and before him, the Neanderthal painted the bones of the dead with red mineral pigment. In the ancient world, colored stones and minerals were used in jewelry, in the decoration of buildings, and as coloring agents in glasses and enamels.

In gems, color was a dominant consideration. In ancient times, ruby or sapphire or emerald meant any hard and gemmy stone of red, blue, or green color. This passion for color in mineral form undoubtedly reached its highest state among the pre-Colombian Indian peoples of Middle America, particularly the Mayan and Aztec, for whom green jade was the most precious of materials. Numerous Mayan burials have been found containing a treasure trove of bright green jadeite necklaces, ear spoons, bracelets, and other adornments.

Today, on a more modest scale, every mineral collector probably favors, in particular, those specimens in his collection which are vivid in color, whether crystals of azurite, rhodonite, crocoite, or crystal specimens of the gem minerals.

It is thus interesting to realize that over the tens of thousands of years that man has sought color in minerals, the most vivid, brilliant and dramatic — and at the same time the most subtle and varied — color phenomenon in minerals was unknown until recent times. This is the phenomenon of fluorescence.

The recognition of fluorescence in minerals, the formation of fluorescent collections, and the rapid growth of this aspect of the ancient interest in minerals have been substantially recent occurrences, since they are a product of the electrical and, more recently, the electronic age. The development of electricity was required in order to provide the various practical sources of ultraviolet light which are required to produce fluorescence; more recently, electronic circuitry has made portable field lights practical.

Today, it is probably true that the majority of the millions of rock and mineral collectors own an ultraviolet light with which they can investigate the fluorescent response of minerals in their collection. Many collectors maintain a display collection of fluorescents, and

some collectors specialize in this branch of the mineral hobby. The reason they do so is directly evident once the ultraviolet light is directed at a fluorescent mineral. Particularly when short wave ultraviolet is used, brilliant and intense colors may spring forth from a mineral specimen which may be unattractive and unpromising in ordinary light, or a more subdued and pastel effect may emerge under long wave light. When a collection includes a selected variety of specimens arranged so that color, intensity, and hue are varied yet properly balanced, the effect is astonishing. Indeed, the fluorescent collection is as much a field of art and aesthetics as it is a field for scientific pursuit.

What is fluorescence and what is its cause? Fluorescence is the visible light produced by certain minerals when these minerals are illuminated by the invisible light rays of an ultraviolet or black light source. Whatever the color, the result is primarily a property of those minerals whose makeup allows them to absorb invisible ultraviolet and to reemit some of this energy as visible light. Impurities known as "activators" play an important role in this process in many minerals. Phosphorescence, which is the continued glow of light after the source of ultraviolet is turned off or removed, is very closely related to fluorescence. Probably all minerals which fluoresce also phosphoresce, though it is only in some that the intensity and duration of this afterglow are sufficient to be easily seen.

Fluorescence-like effects in minerals can also be produced by means other than the use of ultraviolet light and these should be briefly mentioned. Streams of electrons directed at some minerals will produce an output of visible light. This effect is known as cathodoluminescence and is exploited to produce the visible picture in the TV picture tube. Radium and X-rays will produce a similar result called radioluminescence. This is exploited to render X-ray pictures visible. Cathodoluminescence and radioluminescence are only of passing interest to most mineral collectors since the apparatus needed to produce the excitation is elaborate and generally unavailable to the collector.

In some minerals, a momentary burst of light can be produced by heating the mineral to a sufficiently high temperature. This effect is known as thermoluminescence. It has been used by geochemists as a means of dating the time of formation of some minerals since the light produced is the result of energy stored in the mineral, derived from the environment of the mineral at a known rate over geological time. Thermoluminescence is also used by archaeologists to date pottery fragments.

Finally, some minerals will produce light when scratched or struck. This is known as triboluminescence and is familiar to any collector who, breaking quartz, feldspar, or certain other rocks in the dark, notes the flash of light at the point of impact of the hammer.

Some of these luminous effects in minerals were known in ancient times, while others are comparatively modern discoveries. Triboluminescence has probably been recognized for as long as men have worked ores in the deep dark of the mines — at least several thousand years. Phosphorescence was probably noticed in early times by lime makers or dabblers in alchemy who chanced to take certain calcite, or a baked limestone or barite, from sunlight into the dark. It has also been known for centuries that sunlight could produce phosphorescence in some diamonds. The ultraviolet in sunlight is the stimulus for such phosphorescence. Cathodoluminescence and radioluminescence were discovered in the nineteenth century in the course of experiments with electricity and radioactivity.

Fluorescence produced by ultraviolet light is also a discovery of the nineteenth century. About 1800, various experimenters working with Newton's prism discovered that the region just past the visible violet of the spectrum contained radiation since it would darken silver salts, which acted as a primitive photographic plate. Thus was ultraviolet, meaning the region beyond the violet, discovered. The German poet Goethe now enters the scene. Goethe (1749–1832) is certainly much more widely known as a writer and poet than as a scientist, but in fact, he was passionately devoted to the study of the natural sciences, and we may recall that the mineral goethite was named in his honor. He was perhaps the first to recognize and record the fact that ultraviolet light can produce fluorescence in minerals. In his writings on the subject in 1810, which culminated perhaps two decades of study of what we would now call fluorescence, he stated that “beyond the violet where scarcely any color can be seen, the phosphor gave a vivid brilliance” About the same time, another researcher discovered that the radiation from the electric spark, now known to be a rich source of ultraviolet, would produce fluorescence.

We now move to the remarkable Becquerel family of France, three generations of scientists whose work in fluorescence covers a good part of the nineteenth century. Antoine Becquerel (1788–1878) and his son Edmond investigated the response of numerous fluorescent materials to various wavelengths of light, and measured the spectrum of the emitted fluorescent light. Edmond Becquerel (1820–1891) also discovered the red fluorescence of calcite and determined that this fluorescence was due to the presence of some 2.7% manganese in the calcite. This was perhaps the earliest certain discovery of an activator in a fluorescent mineral. He also invented the phosphoroscope, a device for measuring the duration of phosphorescence. In this apparatus, phosphorescence as short as a ten thousandth of a second could be measured.

Then, late in the nineteenth century, Henri Becquerel (1852–1908), son of Edmond, made one of the most important discoveries

in the history of science. He was investigating whether a fluorescent material might give off some form of invisible radiation in addition to visible light. For this purpose, he exposed various materials to sunlight and then placed them on a photographic plate to study the response. At one point, he happened to try a material containing uranium. While waiting for a sunny day, he placed the uranium on top of a still covered photographic plate and put it away in a drawer. Some time later, forgetting that the plate had not been exposed, he developed it. To his surprise, the plate was darkened beneath the place where the uranium had been. This response had nothing to do with fluorescence or phosphorescence. It was due solely to invisible penetrating radiation emitted by the uranium. Thus, from what was intended as an experiment in fluorescence, radioactivity was discovered and the modern world of atomic physics was born. The mineral becquerelite was named in his honor, a fitting tribute to the man whose experiments in fluorescence lead to the discovery of radioactivity. Becquerelite is both fluorescent and radioactive.

It is worth mentioning at this point that there is no connection between fluorescence and radioactivity. It is purely coincidental that many uranium minerals are both fluorescent and mildly radioactive. Other fluorescent minerals are not radioactive and present no hazard.

We now return to the middle of the nineteenth century and George Stokes at Cambridge, England. Stokes (1820-1903) had been investigating the fluorescence of various materials. He recognized, as had others, that the light given off was not simply a reflection or an internal scattering of the light directed at the mineral. Casting about for a name for this behavior, he gave it our present day term "fluorescence" after the mineral fluorite, many specimens of which showed this response so prominently. He did this by analogy with the term "opalescence" which is named after opal.

Stokes also made the important observation that the light given off in fluorescence is always of longer wavelength than the light which, directed at the material, produces the fluorescence. Thus, a blue light might produce a red fluorescence, but a red light cannot produce a blue fluorescence. While certain special exceptions are known, this rule holds so widely that it has been given the name Stokes law of fluorescence. This law plays a key role in the modern explanation of fluorescence, which is based on the quantum theory of physics as developed in the early part of the twentieth century.

By the twentieth century, the investigation of fluorescence and phosphorescence by mineralogists and mineral collectors was under way. Early in the twentieth century, Charles Baskerville and George Kunz, after whom the mineral variety kunzite was named, began a massive investigation of the fluorescent response of the mineral collection at the American Museum of Natural History, thereby creating one of

the first catalogues of fluorescent minerals. In this research, the ultraviolet fluorescence of willemite, colemanite, hanksite, glauberite, hydrozincite, hyalite, fluorite, gypsum, topaz, pectolite, wernerite, wollastonite, calcite, witherite, strontianite, aragonite, cerussite, and other minerals as well, was noted. Mineralogists in Europe soon added the results of their own surveys. By the 1920s, spark lights and other sources of ultraviolet were becoming available to the mineral collector. The building of fluorescent mineral collections was under way.

2 What Is Ultraviolet?

THE ULTRAVIOLET SPECTRUM

Scheelite fluoresces bright blue only under short wave ultraviolet light, and ruby fluoresces bright red primarily under long wave ultraviolet. Some minerals will fluoresce one color under short wave and a different color under long wave. Calcite from Terlingua, Texas, is a spectacular example of this, fluorescing bright blue under short wave, bright pink under long wave. Other fluorescent minerals are more or less impartial. Some willemites and some uranium minerals will fluoresce green; many fluorites will fluoresce blue; many calcites will fluoresce red under either short or long wave.

What is this ultraviolet that produces these spectacular responses in minerals, and what is the distinction between short wave and long wave ultraviolet? Ultraviolet is a form of light, of a kind invisible to human vision. It can be thought of as a particular "color" of light for which the human eye is insensitive (usually), though it is to some extent visible to certain birds and some insects. The important distinction between ordinary visible light and ultraviolet light lies in the difference in wavelength characteristic of each. Light, whether visible or invisible, can be thought of as being a wave motion imposed on electrical and magnetic fields, and such waves have a measurable wavelength. The waves or ripples which can be seen on the surface of a body of water have a wavelength which is simply the distance between one ripple and the next; similarly, the wavelength of light is the distance between one electric or magnetic field peak and the next. The wavelength of light can be measured by an optical instrument called an interferometer. The results of such measurements show that the wavelength of light is exceedingly small. For example, the wavelength of green light is approximately twenty-millionths of an inch, which is to say that in green light about 50,000 ripples of the field can be found over the distance of one inch.

It is useful at this point to shift discussion of wavelength measurement to a scale especially applicable to the measurement of the wavelength of light. Just as it is most convenient to measure the distance between towns in miles, the length of a block within the town in feet, and the height of a curb in inches, it is desirable to use a scale of measurement for light which produces easily handled numbers. Physicists have developed such a scale. This is called the "angstrom" scale,

named after a scientist of the nineteenth century. Using the angstrom scale, the green light referred to above will have a wavelength of 5000 angstroms. The word "angstrom" is usually abbreviated to "A," so that this wavelength is usually written as 5000A.

Light can be of a single wavelength, but the light we ordinarily see will be made up of a mixture of wavelengths. The spectrograph, shown in Figure 2-1, is a convenient instrument for decomposing light into its constituent wavelengths. The essential elements of the spectrograph include a prism or grating to decompose the light and a screen upon which the light is then projected. Light whose wavelength composition is to be analyzed is directed into the spectrograph. Each different wavelength which may be contained in the entering light beam will be projected by the prism onto a different part of the screen. Light projected in this way is called a "spectrum."

The screen upon which the light is projected will be marked off in angstrom units so that the wavelength may be read off directly. If sunlight is beamed through the spectrograph, an astonishing spread of light will be projected upon the screen in all of the colors of the rainbow, and the entire region between about 3800 and 7800A of the screen will appear illuminated (Figure 2-2). Blue light will be seen at about the 4500A mark on the screen, which indicates that this is the wavelength of blue light. Green will appear at a larger value of wavelength, that is, a longer wavelength. This will be followed by yellow, orange, and red at longer and longer wavelengths. This range between 3800 and 7800A contains the wavelengths detectable by the vision of most people.

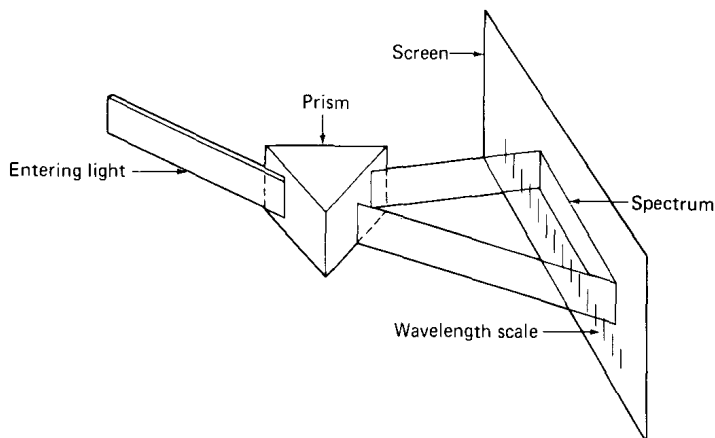


Figure 2-1. A spectrograph contains a prism which decomposes entering light into its constituent wavelengths and projects light of each different wavelength on a different portion of the screen. The screen is ruled so that the wavelength of projected light may be directly read. A quartz prism would be required if short wave ultraviolet is to be examined. A spectroscope differs from a spectrograph in that it contains optics which allow direct view into the prism so that the spectrum is seen directly, rather than by projection on a screen.

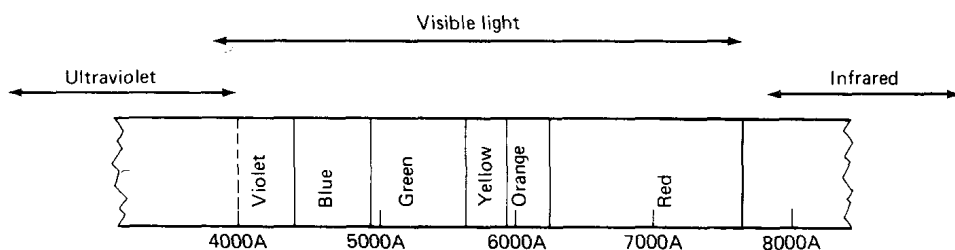


Figure 2-2. The visible portion of the light spectrum. Some ultraviolet and infrared will be projected even by a spectrograph intended for visible light.

To the right of the 7800A location the screen will be dark. Nothing will be seen in this portion of the spectrum. Yet a form of light energy is being projected on that part of the screen also. This can be confirmed by holding a thermometer in that location. The thermometer will show a temperature rise due to the presence of radiation. This is the infrared region of the light spectrum. While it is not visible to human vision, some desert snakes can detect infrared, and these snakes use this capability to home in on prey at night.

We now consider the region to the left of the 3800A mark on the screen — a region where, again, the screen is dark and nothing is seen. Once again the thermometer can be used to confirm the presence of radiation. Alternatively, a piece of fluorite held there will burst into visible fluorescence, and a photographic plate held there will be quickly darkened. This is the ultraviolet region of the light spectrum. It is this radiation which produces the startling variety of fluorescences in minerals.

Just as the visible portion of the light spectrum is divided into a number of subregions (that is, colors), ultraviolet is divided into several regions which differ somewhat in their properties. These regions, shown in Figure 2-3, are as follows. The “near” ultraviolet includes those wavelengths between 3000 and 3800A. This is what fluorescent mineral collectors call “long wave” ultraviolet since most of the radiation produced by long wave lamps is contained in this region. “Far” ultraviolet lies between 2000 and 3000A, and corresponds to the mineral collectors’ “short wave” since radiation produced by short wave lamps is centered between these limits. The ultraviolet region of the spectrum continues further to the left, to wavelengths shorter than 2000A, into what is called the “extreme” ultraviolet. Extreme ultraviolet is of little interest to the mineral collector for a number of practical reasons. It is very hard to generate with any useful intensity, and further, a filter would be needed to screen out the visible light which is also produced. A practical filter capable of passing extreme ultraviolet is not available. Also, extreme ultraviolet is extremely reactive with the oxygen in the air. The oxygen molecule is decomposed by extreme ultraviolet and the ultraviolet is absorbed