Introduction

Relatively few of us are lucky enough to have and use a wide range of makes and models of microscopes. Work-place microscope labs often have little variety in brands or models, so as to reduce costs for maintenance and accessories. But because I have moved around a few times since the early 1970s, different microscopes have been available for my geological field research and education. An enjoyable if challenging task in the 1980s was teaching optical mineralogy and petrography with polarizing microscopes (pol scopes), in advanced undergraduate courses in academic geology programs. In recent years, I have been servicing, refurbishing, and selling microscopes in a part-time business.

There is nothing mysterious or strange about the polarized light accessories used in a petrographic (geological) microscope. Its brightfield capabilities continue as in any good biological microscope, with the addition of polarizing filters placed above and below the sample, at least one of which can be easily moved in and out of the light path. The circular stage rotates to show how different orientations of the sample affect polarized light, but it can also be fixed in place for other uses. A Bertrand lens (essentially a pinhole with a magnifier) is available to observe polarized light patterns on the back of a higher-power objective. Many crystalline materials (organic as well as inorganic) produce birefringence effects with both polarizers in place, and views of some biological samples can show improvements similar to the darkfield technique. See other Micscape articles and the references cited at the end for more about polarized light microscopy (PLM for short).

In recent years, it has become possible to obtain a high-quality used bench top polarizing microscope for a small fraction of its new price, so that a step up from a student or less-capable model is feasible even for modest pockets (as in my case). Although certainly not a trivial cost, you might with some work and luck find a very good machine for a price between US $1000 and $2000 (about 800 to 1600 Euros), although with an expectation that the product will need some cleaning, adjusting, and likely another accessory or two. Yes, there are number of used or even new student-size pol scopes available for less money, and they mostly function OK, but they are at another level and that is another article.

How to Get One?

If a dealer is nearby, you might call or visit—even new microscope dealers might have some good "pre-owned" machines in stock. There are always nice
examples for sale by dealers on the internet, which can be found with a search engine such as Google or Yahoo. The hang-up here might be cost. You will note right away that prices for polarizing microscopes are half-again to double the cost for biological brightfield versions of the same model. Asking prices for like-new used bench top polarizing microscopes from dealers can run from $4000 to $8000, sometimes higher. Pol scopes start out at a higher price when new because parts for pol scopes are more expensive to produce, and they are sold in much smaller numbers than biological models, so it is a matter of production costs. In addition, a dealer will add value by cleaning, adjusting, repairing, replacing parts, testing, and guaranteeing a complex machine, which has to be reflected in the price. But if you have the where-with-all, buying from a dealer will almost certainly mean your instrument is in good function and good condition, and if it is not, you have some recourse. Dealers want and need happy customers.

But then, like your fellow microscopists around the globe, you could watch what comes up at internet auction sites such as eBay. Here final prices are often a bargain, sometimes ridiculously low (10% to 20% of new cost), but obviously there is a real risk that what arrives (eventually) is less than satisfactory. Assuming this is your route, what might you find with a price between $1000 to $2000 or so, using a bargain source such as eBay? And, what should you know about the particular makes and models, other than what the seller describes or you can glean from the internet?

In this article, I will describe six of the best research-quality bench top polarizing microscopes, made from the 1970s to 1990s, that I have direct experience with, and have seen in various conditions for sale on eBay. Why that age range? The major companies made significant improvements in optics and functionality after the 1960s, achieving excellent mechanical quality as well. The modular parts that are needed for polarizing microscopes were perfected, and have not changed much since then. Starting in the 1990s, the big companies re-developed their instrument lines into what appear to be more sophisticated models, usually with infinity tube-length optics and ergonomic, stylish designs. They are, no doubt, superlative machines. But the people and companies that bought them new are still using them, so relatively few are as yet available on the used microscope market. And, they are expensive. More to the point, I have very little personal experience with 21st century scopes. From my perspective, the 1970s to 1990s were the golden age of microscopes.

Disclaimer

It is understandable that you might object to some of my characterizations, or complain that I have left out a microscope you know to be top-notch. My descriptions are naturally subjective, and limited to machines I have actually worked with. Also, I am not a professional microscopist or trained service technician. However, my experience includes at least as many others that in my
judgment are not quite as good, even if all of them have certain fine qualities. In truth, I have never met a geological microscope I did not like.

Criteria for Judging Pol Microscopes

Assuming good used condition (unmarked glass, clear filters, clean machine, nothing broken, all functional, not abused), criteria for judging petrographic microscopes include:

**Lighting.** Geological microscopes need a bright light source because of light loss by the polarizing filters. Also, cross-polar views need to be evenly lit to judge differences in birefringence across the view. There should be a diaphragm (iris) below the field lens and other at an adjustable condenser, so that you can achieve Kohler illumination. Newer systems use a halogen lamp, either pre-focused or adjustable, which is cheap and easy to replace.

**Focus controls** should be neither loose nor too tight. The best systems have tightness or tension that can be adjusted by the user without any disassembly, usually related to the coarse focusing knobs. Minerals often have structures that can be studied by slightly changing the focal plane, so there needs to be smoothness and precision.

**Angular rotational scales and controls.** The circular stage should have degree gradations (a goniometer), with a stop screw and (possibly) audible clicks at regular intervals. One eyepiece needs a focusable crosshair reticle (micrometer marks on it are a plus), and the eyepiece might lock in place with a pin and slot. The polarizing filters must be properly aligned, so that extinction angles can be studied and measured (with the stage scale) relative to the crosshair. It is helpful if one or both pol filters can be rotated according to degree scales, and to be sure of angles relative to a compensating plate.

**Ease of centering** the objectives, the circular stage, and the condenser, so that the view and the stage rotate around the same center point. A good system has centering screws that work smoothly and do not allow individual objectives to wander off center. The stage also should be easy to center with screws or bolts (relative to one or more of the objectives), and it will stay that way during use.

**Accessories.** Because they often are not included in used scope sales, accessories need to be available for adding later, either through eBay or via commercial sources. They tend to be expensive. All good pol systems need one or more light-wave compensating plates, at least a whole-wave (1st order red) and if possible a ¼ wave (mica) plate, and maybe a quartz wedge. Although the older 4x12 mm plate size is fine, the newer size of 6x20 mm indicates a larger, brighter, light pathway. It is also really nice, if not absolutely necessary, to have a smooth-operating x-y mechanical slide holder on the stage. They are made with
low or horizontal control knobs that will not interfere with objectives when the stage is rotated. Hard to find, and expensive when you find one.

**Bertrand lens.** Conoscopic observations with petrographic microscopes assist the identification of minerals, and sometimes to estimate their compositions as well. It is possible to pull off an eyepiece and look down the tube for this purpose, but every good pol scope will provide a Bertrand lens instead (same tool as used to center phase contrast rings). It will be built into the head, or in an intermediate tube beneath the head, and it can be moved into or out of the light path. The best machines will also provide a way to focus it. To help make a proper concentrated light cone, the condenser should have a flip-up top lens for this higher-power conoscopic observation.

**Optical quality.** You should expect wide, sharp, planar views, with good contrast and brightness. The polarizing filters should be responsible for any and all birefringence in the minerals under study. The problem of optical parts adding their own polarization (in unwanted directions) is why companies have to put extra effort, and money, into designing and constructing pol parts. Pol scope optics are said to be strain-free, that is, their glass is cooled and lenses constructed so that they add no polarizing effects. In addition, such effects from internal glass layers in the lenses, mirrors, refractors, and prisms have to be designed out. Binocular heads, with their extra prisms and mirrors, are especially harder (and more expensive) to make for pol scopes than are monocular heads. This is why monocular heads have been especially common in polarizing systems, even at the higher end. However, the best pol scopes in my benchtop group will offer both binocular and trinocular heads, and you should have one or the other.

**Objectives and oculars.** Many rocks are coarse enough to require low power objectives. A good system will have at least 2.5 or 4x, 10x, and 40x pol (P or Po) objectives, and as a 4th piece, a 20x or 60x is more useful than a 100x objective. The 40x power is also used for conoscopic observations. Expect good plan achromats. Also in the best pol scope, the eyepieces should be widefield, high-eyepoint types. Top systems might use objectives that are paired with specific compensating eyepieces, designed to work together. Here is a poorly-kept secret: many 'regular' non-pol objectives of good quality will work fine in a polarizing microscope, without noticeable strain effects.

**Look and feel.** The best microscopes have parts that move smoothly and easily where they should, but are rigid and solid where they should not. They have close tolerances, polished contact surfaces, metal gears, ball bearings, and good finishes. Lesser machines have eyepieces that rattle around, condensers that will not stay put, stages that stick or wobble, objectives not parfocal — it goes on and on. The frame should be strong, solid, and heavy, especially if you are going to take photomicrographs. Your hands should fall naturally to the controls, and various parts should be easily found when needed and out of the way when not
needed. And it should be good looking — aesthetics are important. These things affect your pleasure in owning and using any microscope.

**Maintainability.** Finally, the best scopes can be disassembled and reassembled as needed for cleaning, lubricating, adjusting, and repairing. That ability makes regular care a lot easier, and with it a quality microscope will provide fine service for a life time.

**The Top Picks**

Six machines represent my picks of the best used polarizing microscopes with affordable prices, meaning less than $2000 or so in an auction setting (fixed-price dealers, including me, might want more than that). I have put them in order of likely cost and my personal preference, with the best one last.

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**Leitz Dialux, Early 1970s**

Leitz deserves the high esteem that owners and users hold for their products of the pre-Leica years. The black Ortholux and Dialux pol scopes of the 1960's and early 70's are close to the look and feel of their superlative contemporary, the Wild Heerbrugg M21, and Leitz sure sold a lot more (in the USA anyway), so many parts and accessories are available on the market. In the 80s, Leitz changed over to a blue-gray rectangular-box design for its scope stands, which were newer looking but (I am told) not better machines.
I spent portions of several days cleaning and adjusting a Leitz Dialux that is actively used by a fellow academic geologist. After 35 years it shows only minor wear, and it could probably give perfect satisfaction for another 35 years, at least. He remembers a price around $6500 in 1971, with another $1500 for a kit of accessories including wave plates and a mechanical x-y point-counting stage.

This one has five large, excellent objectives, marked PL 2.5/0.08 170/-, 10/0.25 P 170/-, NPL 16/0.40 P 170/-, NPL 40/0.65 P 170/0.17, and P 63/0.85 170/017. The turret is large enough to hold all five plus centering screws for them. The trinocular head has a Bertrand lens built into it, and uses Periplan GF10x eyepieces. Both the analyzer and the polarizer filters can rotate, with a slot for the 4x12 wave plates in the pol nose. There is a separate power source for the 15 watt tungsten filament lamp.

For some reason, in many photos the Dialux looks rather small, but in fact it is a full-sized bench top machine, not a portable student stand. Its heavy, rigid frame is very good for photomicrography. Some people who wish to adapt certain digital cameras (such as the Nikon Coolpix 990/995) seek out a Periplan objective that has a screw-on eye-guard (this example does not). After removing the eye-guard, the threads are the right size to screw the objective directly onto the camera. It then becomes an excellent photo relay lens that can slide into the trinocular tube and easily hold the light weight camera.

You might think that people who use this older black-enamel style will envy geologists who have newer machines, but at least in this case, my colleague knows that his Leitz is close to the acme of function and design in petrographic microscopes. But not everyone has his insight, so you might find a real bargain price for this model.

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American Optical Series 110, Mid-1980s
This is the polarizing version of the Microstar model, built in the USA shortly before and after the company changed its name to Reichert (it later stopped producing American microscopes). As A.O. owners will attest, the 110 model is a large, solid, well-designed, high quality microscope, with smooth operation and good function.

The four A.O. infinity-corrected advanced plan-achromat objectives include a 4x/0.12, 10x/0.25, 20x/0.50, and a 40x/0.66. Also available were 45x, 50x, and 100x objectives, although they might not all be strain-free. They produce very good, wide, sharp, high-contrast views. The graduated circular stage is easily centered with attached knobs, but there is no provision to center objectives.

The binocular or trinocular head (which might show very slight induced birefringence) is attached to an intermediate tube with a polarizing filter wheel, while the strain-free monocular head has an internal diaphragm, a flip-lever analyzer filter, and a separate Bertrand lens lever with lens focus. The binoc head has two 10x wide field strain-free eyepieces, and the monocular head uses a matching 10x wide field eyepiece with a crosshair reticle (six different eyepieces were made).

There is a 6x20 mm plate slot in the nose. The centerable condenser is the 1.25 n.a. Abbe aspheric type with a swing-out auxiliary lens. The field lens has a rotatable polarizer and there are control knobs for an internal daylight filter as well as a field diaphragm. The thick enamel finish on these stands holds up well and is
easy to clean (I use a good car wax). The 20 watt halogen lamp in the base pulls out on a holder clip, very easy (and cheap) to replace.

In the trinocular version, a photo (camera) tube is easily removed and replaced with a cap as desired, and there is a lever to switch between the tube and the eyepieces (100% each way). I have used a Nikon 990 digital camera with the trinoc version, attached to an eyepiece inserted into the photo tube. The camera images are nearly parfocal with the objectives, making photography with this microscope very easy and convenient.

Good looking, well made American hardware, with fine optics, and pleasant to use. Many of us regret the end of this distinguished company’s products after its merge into the Leica conglomerate.

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Zeiss Standard, Late 1970s

During our time frame, Zeiss made a very popular polarizing petrographic microscope based on the various Standard 14, 16, and 18 stands. It used the famous Zeiss Pol objectives and one or two intermediate tubes for polarizing accessories. Zeiss pioneered modular designs with the Standard, which soon became the norm for all makers. Many options and accessories were produced, so a real mix-and-match is possible for the numbered variations.

Some versions of the Standard stand had a monocular head and somewhat simplified layout, which they marketed as student lab scopes. Standards are a little smaller and lighter than other microscopes in this
list, so it is the only one that is reasonably portable. For benchtop research use, Zeiss provided intermediate tubes containing an rotating analyzer, with or without a Bertrand lens, an Optovar (magnification changer) with a Bertrand lens, a binocular or trinocular head (some with with a gear to keep the eyepiece crosshair aligned), and more complex assemblies of substage condensers and pol filters. Some of these parts, including objectives, were shared with the high-level Universal or Photomic models, making this machine a real "pocket rocket." All were very well made, as everyone seems to agree.

In this example's binocular head, the Zeiss Cpl W (widefield) 10x eyepieces are high eyepoint (goggle) type. More commonly in used Zeiss pol scopes, you will see older Kpl oculars that are not widefield. Those with a cross hair or other reticle have helical focus. The two intermediate tubes include an upper one with a calibrated rotatable analyzer (polarizing filter) in a sliding plate, and a slot for a 4x12 mm compensating plate (Zeiss "rot 1" whole wave plates remain common). The lower tube is a Zeiss Optovar which has a wheel with stops for additional magnifications of 1.0, 1.25, 1.5, 2.0, and a Bertrand lens (marked Ph for its use in centering phase contrast objectives).

The four 160 mm Zeiss objectives in my example include a Plan 2.5/0.08, a 10/0.22, a superlative 25/0.60 Neofluar with retracting tip, and a 40/0.85 with retracting tip. The 100x/1.25 oil is more rare. These all use a system in which you turn two rings in the objective barrel to center the view. The large rotating circular stage in this example has a fine Zeiss X-Y slide holder (a real treat), or a smaller circular stage with a built-in X-Y holder used in Universals might also be installed. The condenser has a diaphragm, a flip-up 1.3 n.a. top lens (red lettering for the pol version), a swing-out auxiliary lens, and a holder for the rotatable polarizing filter.

The lighting system in this one uses a 10-watt halogen bulb with a brightness control knob in the base, and an on/off switch in the power cord. Other versions have a 15-watt tungsten filament lamp powered by a separate transformer. The instruction manual for this model is a free PDF file on the Zeiss company website...too bad many other companies are not so helpful.

All of the great qualities that we expect from Zeiss made their Standard model extremely popular and in wide use even today. I have read some opinions that Zeiss lenses are superior to all contemporaries, but to my eyes they are not
better than optics of the other major makers, and often are not very planar. Many older Zeiss Standards suffer from delamination of internal lenses and filters, especially the analyzer (upper pol filter). I know of no practical way to repair them, so you must find replacements for really bad ones (delamination around the edges might not hurt the view much).

Otherwise, it is a great pleasure to use this scope, and you will be happy to have one.

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**Nikon Labophot, Mid-1980s**

The Nikon Labophot was an "entry level" benchtop scope, less expensive than the Optiphot line. I have never seen an Optiphot pol scope, but the same modular parts should fit either model.

The Labophot pol version has some interesting features. A large whole-wave compensating filter is permanently mounted in a filter holder over the polarizer, which you can swing in and out and also rotate. The polarizer (also rotatable) mounts in a removable holder in the foot directly over the field lens. The Achromat condenser has a flip-up lens, iris, and centering screws. The graduated circular stage is centerable. The analyzer is in a slider plate in an intermediate tube accessory. The binocular head has a built-in Bertrand lens on a dial beneath the eyepiece tubes, which works well. The eyepieces are Nikon CFW 10x, with one being a focusing "CM" containing a crosshair with a graduated horizontal axis. The 20-watt halogen lamp is in a holder that plugs into the back of the base, cheap and easy to change. There is an on-off and light intensity dial in the front.

In the five-place nose turret the 160 mm Nikon pol objectives include a 4x/0.10, 10x/0.25, and 40x/0.65 with retracting tip. A 20x/0.45 and 100x/1.25 oil with
retracting tip were available as options. They are very similar to Nikon’s biological E Plans in quality, which is excellent.

I was very impressed by the Nikon optics in this scope, which provide really wonderful wide, bright, sharp, planar images. In fact, the view has not been surpassed by any other in my experience, the biggest plus for this machine. Also nice is the large size of the controls, good stand design, and overall smooth and easy operation. Negatives include a lack of individual objective centering, no slot for a compensating plate (although the one over the field lens serves well), and sorry to say, this stand is not noted for its durability. But oh my, those Nikon optics!

The Labophot (and successor called Labophot 2) biological scopes are common on the used market, but the pol version is relatively rare.

Wild Heerbrugg M21, Early 1970s

This is the polarizing petrographic (geological) version of the wonderful Wild M20 microscope, handcrafted in Switzerland and considered by some experts to be the best microscope ever made.

The four achromat objectives on my example are a 4/1.0 Pol, Pol 10/0.25, Pol 20/0.45, and Pol 40/0.65. A Pol 100/1.25 oil immersion lens was available, as well as a very rare 50x. The 20x, 40x, and 100x lenses have spring-loaded tips to reduce contact damage. They
each have an easy if unique 2-knob centering feature, and they fit into a quick-release turret nosepiece. The head attached to a body tube with a rotatable calibrated analyzer, and a slot for a 4x12 mm compensating plate. The large Pol (strain free) condenser has a flip up top lens, a diaphragm, and a swing-out filter holder. Beneath that, a swing-out polarizing filter can be rotated. The field lens is adjustable and a field diaphragm is built into the light tube, so that Kohler illumination can be achieved.

The strain-free monocular pol head had six different eyepieces with crosshairs made for it, and it includes a built-in adjustable, focusable Bertrand lens in a none-too-handsome aluminum head barrel. If you can make do without a Bertrand lens, a special version of the binocular head was made with a quartz filter to cancel strain effects, but this head is very rare. As binocular viewing beats one-eye almost any time, it is not hard to accept slight birefringence from using an M20 head, which is a perfect match.

An intermediate photo tube with attached camera tube was available, not a trinocular head but it worked to the same effect. Another intermediate tube can be installed for incident (reflecting) light, but it needs different objectives (easy to add in a separate removable turret).

The Wild MTr3 power source is switchable for 4 international voltage inputs, and it has an on-off switch and four output power levels. Several other transformers were made as well. They power a 20-watt tungsten filament lamp with a brass sleeve, which is becoming rare and somewhat expensive to replace.

I expect that all of the parts that convert the M20 biological scope into an M21 could also be used to create an M21 EB (the M20 EB was an extended-base version of the M20). However, I don’t know if an M21 EB was actually sold by the company. A special, large lighting system rig was available, into which the stand could be mounted to provide powerful lighting for phase contrast and ultraviolet fluorescent applications.

No other microscope of any age matches the feel of quality presented by the Wild Heerbrugg M21 (and its siblings). If you do not care for more modern designs, this is one for a lifetime.
Olympus BH-2 BHTP, Late 1980s

I have to confess up front that this particular Olympus BH-2 BHTP (pol version of the BHT) is the microscope I prefer over all others, including some great very large research instruments I have used in past years. It has taken me a long time and a steady flow (or flux, as scientists might say) of dollars to obtain and refurbish all of its parts and accessories, but now that it purrs like a kitten, I can tell you it was worth every penny and frustration. It has earned a permanent and revered place in my research lab.

Olympus developed the BH-2 model lineup from its good-but-homely BH series of the 1970s. They were a big step up from older styles of lab and research microscopes produced in previous years, and it appears that the company went all out with a huge effort to get it right, no matter what it took. It has a fairly large stand but still can fit into a hard case for transportation (not something that should be routinely done, however). Parts and controls are a good fit for my big hands. There was also a slightly larger edition with a wider base and very powerful 100-watt light source called the BHSP (pol version of the BHS).

As in the BHT (as opposed to a BHTU, which uses an inward-facing turret), the objectives are mounted in a quick-removable nose turret, which for the BHTP has side screws to center 3 of its 4 objective spaces. The large circular stage can also be centered, and it can be set to click at every 45 degrees of rotation. The objectives are pol versions of the excellent DPlan line used in the biological version. The super-wide-view SPlan objectives do not have strain-free versions, but they probably work fine on a pol scope anyway. I have a set of 4/0.10, 10/0.25, 20/0.40, and 40/0.65 DPlan Po objectives mounted on the scope, with
100/1.25 oil, SPlan FL2/0.08, and Olympus dispersion staining objectives on a separate spare turret. Very handy. All are 160 mm tube length, 0.17 cover slip.

The 20 watt halogen lamp in a holder in the base is bright enough, although just barely. The intermediate body tube contains a slide-out analyzer, a rotate-in Bertrand lens with a separate focus, and a 6x20mm slot for wave plates. The binocular and trinocular heads have a gear that moves the eyepieces in and out to maintain the focus for different eye widths, very slick. There was a monocular head made, but thank goodness it is almost never seen. A line of compensating eyepieces labeled WHK (field number 20) is available in 8x, 10x, 12.5x, and 15x powers (only the 10x is common) and they work extremely well with the DPlans. I use a WHK 8x as a photo relay lens attached to a Nikon Coolpix 990 for photomicrography, which is close to ideal. The excellent PM-10AD automated film camera system for this model has become relatively cheap and easier to find, now that fewer people use film.

I paid only $1200 for the stand with some "issues" and no accessories, but it would take some luck or hard bargaining to find one under $2000 in fairly complete operating condition. It is easy to work on, a big plus for maintenance.

I cannot say that any one feature of my BHTP is better than the best on the other excellent microscopes. It is just that everything on this machine is really good, not just some or most of it. Great quality and design, excellent optics, all operations first rate, good looks, ergonometic controls, accessories and spare parts available—everything a petrographer could want, and more.

**Final Comments**

In conclusion, I wonder if the relative scarcity of these six microscope models on the open market is due more to their owners’ unwillingness to trade them in for newer machines, than to relatively few being manufactured. With instruments so satisfying and functional as these, it would be understandable. And after all, the polarizing options we use have stayed pretty much the same during the past 40
years. With care and maintenance, any of these microscopes could provide fine service virtually forever.

Some machines, such as the Leitz Laborlux of the 1980s, would surely be on my list except that I am not personally familiar with them. Others are probably too expensive for now, but as years pass, they likely will become more accessible for normal pockets through eBay and other popular sources.

Comments and other opinions are always welcome: contact the author Greg McHone

Useful Links:

Olympus microscope forum on polarized light microscopy

Molecular Expressions polarized light microscopy

Petrographic scopes and thin sections

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