Guide for building a home petrographic microscope

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Original guide for building a basic smartphone microscope: https://www.instructables.com/id/10-Smartphone-to-digital-microscope-conversion/

Supplies needed:

- ¼" plywood or craft wood, cut into three rectangular 5"x8" boards
- Power drill with standard wood drilling bits
- 2" to 2.5" hole bit
- Battery-powered LED light source with on/off switch
- Scrap 2x4 wood, cut into two ~1" wide pieces
- 2-4 wood screws, ~1" in length
- Velcro stickers
- 2 pieces of polarizing film, protective plastic covers removed
- 4 count ¼" x 4.25" long hex bolts
- 8 count ¼" washers
- 12 count ¼" nuts
- 4 count ¼" wing nuts
- 4" lazy susan mount (https://www.amazon.com/gp/product/B074QJ24RX/)
- Thin plexiglass sheet (1/8" at most)
- Plastic cutting knife, straight edge
- Clear silicone adhesive or other plastic-safe glue that is easy to work with
- 2 collimating lenses, 7 mm (the kind in a laser pointer, but they are often glued in so you may want to buy them directly) (https://www.amazon.com/Collimating-focusing-Diameter-Diodes-AixiZ/dp/B074MDQDLZ/)
- Reaming tool or wood files to smooth and widen holes
- 4 count #6 machine screws (these need to have flat, not sharp ends)
- 4 count #6 nuts
- Digital camera that can be stably placed vertically over a lens (phone camera is ideal)
- Thin section for testing focus and centering
- Sand paper and/or electric sander to remove sharp edges
- Optional: scroll saw, or oscillating Dremel with wood blade

Plans for an inexpensive, basic polarizing scope:

1. First, take the three 5"x8" boards. These will form the main stand and frame for the microscope. The bottom board is the base, the middle one is the specimen stage board, and the top one holds the objective lens(es) and supports the camera (which acts as an adjustable ocular lens if you use its built-in zoom function).

- Place all three boards in a neat stack and drill through all four corners for bolt holes with a ¼” drill bit. I recommend clamping them together so they don’t shift. Use a file or reaming tool to smooth and slightly widen the holes; the ¼” bolts should slide smoothly and easily through them. (Note: if you lack a reaming tool, you could drill 5/16” holes instead, but the boards may wobble more.)

- Mark the boards in one corner with numbers to indicate which board is which, and with an “up” arrow so you can reassemble them correctly later. If making a large set, you can also label them with a “serial” number or letter.

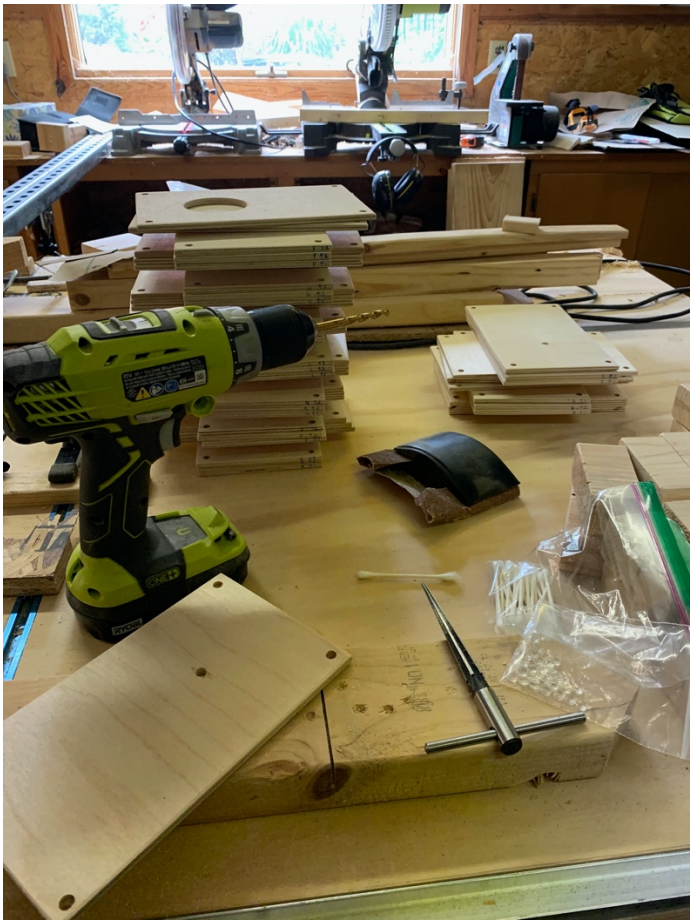
2. After this step and throughout, briefly use the sand paper or a sander tool to smooth any sharp or splintered areas where you have drilled and cut.

3. Measure and identify a position that is ~3” from the S end of the middle (specimen stage) board, in the very center in the E-W orientation. Place the rotating lazy susan mount centered over the position you identified, and ensure it will not collide with the corner bolt holes when rotating; if necessary, slightly adjust the position to ensure this is the case. Outline the hole of the mount with a pen or pencil.

4. Clamp the board down and use a hole bit to cut a 2” hole in the center of the board. Drilling a small, center pilot hole is recommended for aligning and stabilizing the hole bit. With plywood, the lowermost layer is likely to splinter unless you have a very sharp bit and go slowly; if necessary, you can use a wood file and some sandpaper to clean up

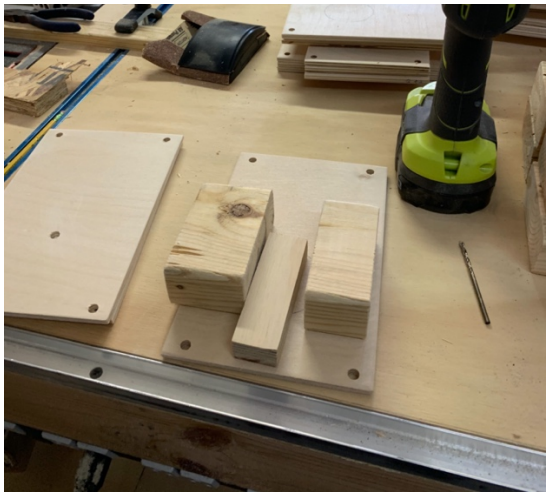
the hole and smooth it out after drilling. If you are making a larger set, a drill press is recommended instead (and note that it should work to make a smaller hole, probably as small as 1” in diameter, if that is more achievable).

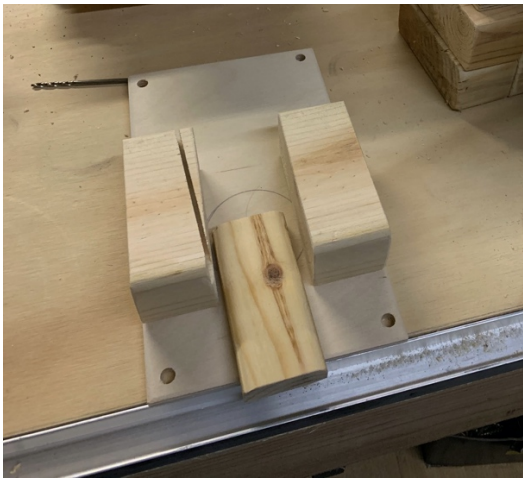
5. Turn the top (objective) board upside down, and place the specimen stage upside down onto it. Use a ruler to measure and clearly mark the very center of the 2” stage hole on the underside of the top board, to mark the position where the objective lens should go. Drill a ¼” hole in the spot you marked. Set aside for now.



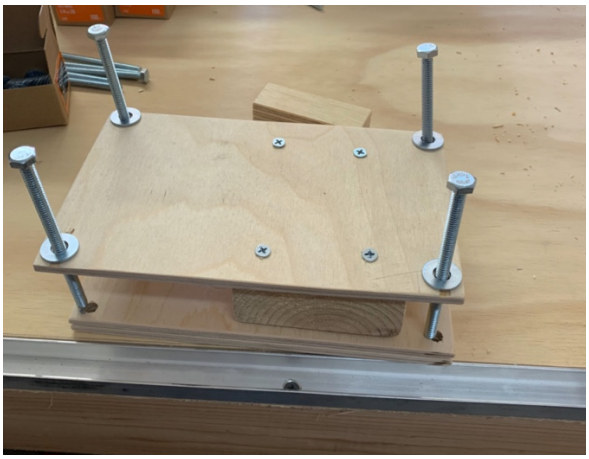
6. Turn the lower and middle boards right-side up, and again use the 2” hole to outline the stage center on the lower board, to help align the polarizer and light source. Find or cut two scraps of 2x4 lumber to use as supports for the lower polarizer. They should be at least half an inch wide on top and identical in height, which should in turn be taller than the height of your light source (the 1.5” side of a 2x4 works well for this height). Place the wood segments to the E and W of the marked stage center, leaving ~1.5” of space between them for the light source; you may also want to fit a scrap of wood that can

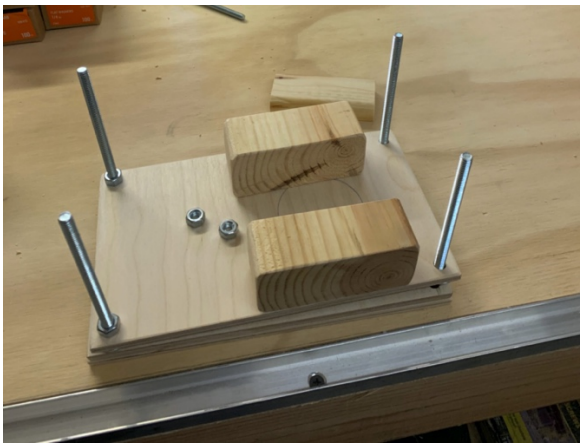
support the light source for easier access, shown below. Carefully turn the assembly over; drill and affix the wood segments to the base board from beneath using wood screws.





7. Attach four ¼” bolts with washers through the corners of the base from below, and secure with nuts from above. Tighten these nuts well to prevent the assembly from wobbling. You now have a completed base for your microscope.

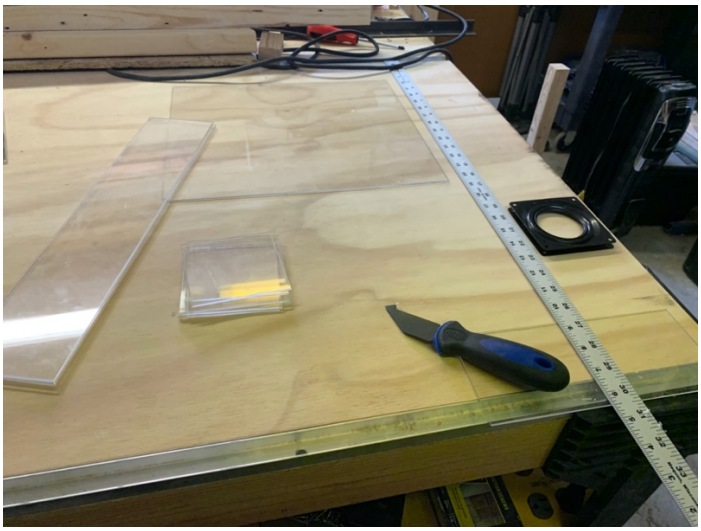


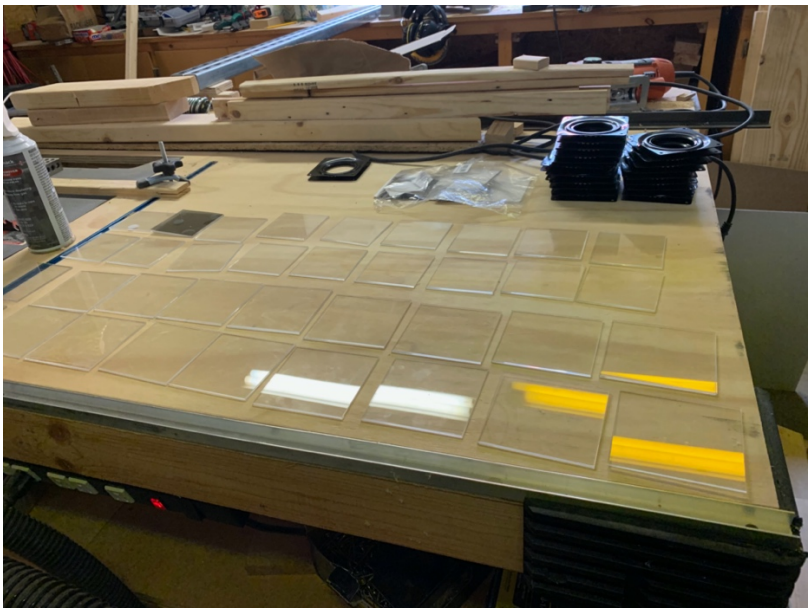


8. The next step is to make the lower polarizer. Adhere Velcro stickers to the tops of the 2x4 segments. (<u>NOTE</u>: The design explained here is for the third prototype, where the lower polarizer is fixed (like in a petrographic microscope) and the upper polarizer can be

removed or added. The planned, fourth generation design will actually have a fixed upper polarizer and removable lower polarizer, primarily because it is difficult and slow to add and remove the film from the top of the assembly. So an alternative to the design explained in steps 8-10 is to make the lower polarizer removable using a longer piece of Plexiglas or hard plastic, making sure the alignment is E-W and clearly indicated.)

9. Cut out two square pieces out of a sheet of Plexiglas by scoring and breaking it with a plastic cutting knife and a straight-edge; one piece should be 3” and the other 4” square. Sand the sharp edges with a piece of sand paper.





10. Using plastic-safe glue or silicone in the corners, glue a piece of polarizing film to each of the 3” square pieces of Plexiglas. Orient them to polarize in an E-W direction (compare to a microscope if necessary to check this). Place matching Velcro stickers to the E and W sides on the underside of the plastic square, so they will attach to the stickers placed in step 8. The assembly will now produce an E-W plane-polarized light source, but the film can be removed if necessary. A battery-operated LED light should comfortably fit below the film.

11. Now it is time to start assembling the stage. Use silicone or plastic-safe glue to attach the 4” square of Plexiglas to the top of the 4” lazy susan mount. Allow it to dry before using.

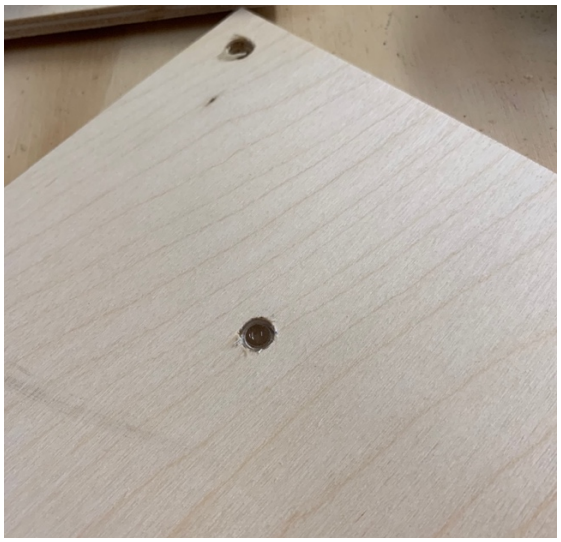
Silicone

12. Place wing nuts and washers onto the four corner bolts of the microscope and lower them until they are about ¼” above the lower polarizing filter mounts.

13. Orient and place the stage board onto the corner bolts and lower until it is resting on the washers. Check and adjust the stage until it is more or less level, keeping it slightly above the polarizing film so it does not touch.

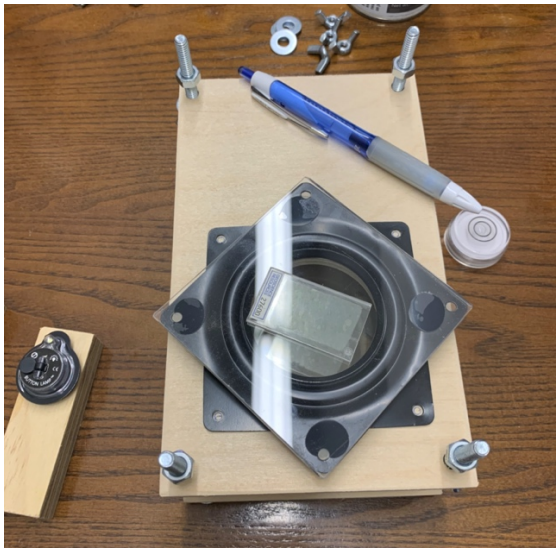
14. Return to the top board that you set aside. File or ream out the ¼” hole <u>from above</u> until the hole is smooth and the collimating lens fits snugly when inserted <u>from beneath</u> the board. Note that some collimating lenses are one-sided, while others work from both directions; check the orientation of the lens to make sure it is facing the correct direction before inserting (to do this, hold it up to your camera lens and attempt to focus on a nearby object to test this). Insert the lens, then use a narrow but soft item (a Q-tip would work; note that the plastic lenses scratch <u>easily</u>) to make sure the lens is snug and flush with the underside of the board. A small bead of silicone on the side of the lens or small sliver of double-sided tape may help it to stay if it is not a tight enough fit, but do not cover the lens at all.

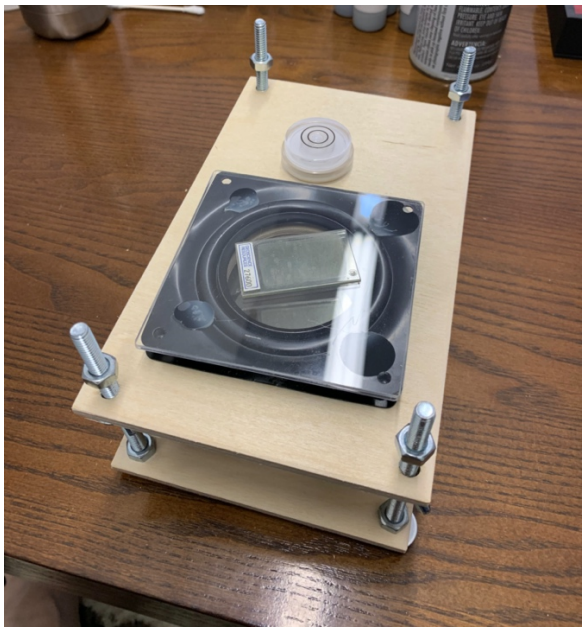
(This image shows an older, square prototype, but the process of widening the lens hole is the same.)

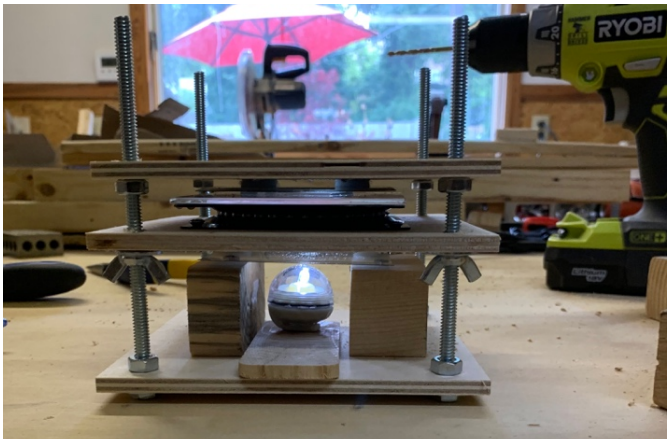


15. By reaming or filing the hole from above, the lens hole should have been made very slightly wider on the top side of the board. You can now place the second lens immediately on top of the first for much better magnification. As above, you could place a small bead of silicone or plastic-safe adhesive on the side of the lens to help hold it in place (but do not cover the lens). Make sure it is properly aligned before any permanent mounting.

16. Set the lazy susan mount on the specimen stage board, with the plexiglass-side facing up. This is the rotating stage. Place a sample thin section onto the center of the stage to test focus. Add a nut to each corner bolt, lower all four nuts until they are about one inch above the stage board, then orient and slide the top objective board onto the frame so it rests on the nuts. Turn on and position the light so it is visible through the objective lens, turn on your smartphone camera, and align the camera so it is viewing directly through the lens. Gently raise and lower the four nuts and the objective board until the slide is reasonably in focus and the objective board is more or less level (it is all right if this is a little wobbly for now; you will reposition and tighten it later).



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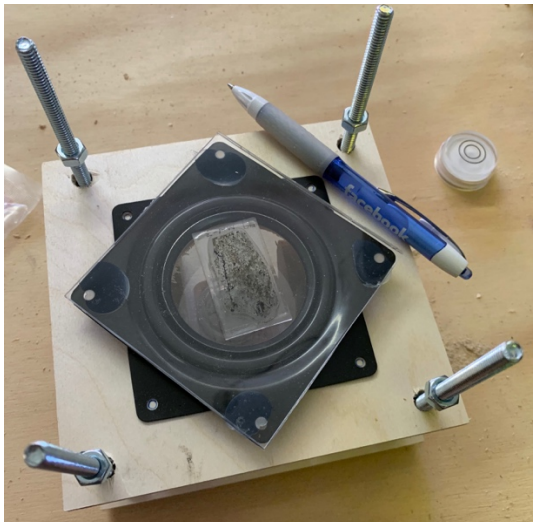
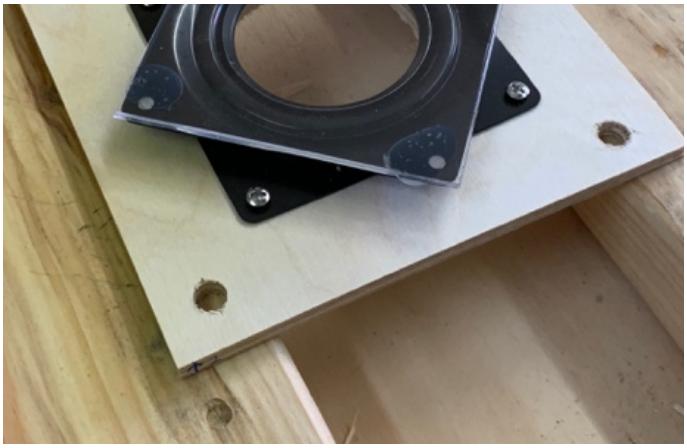
17. Rotate the specimen stage and watch through the camera to determine the center of rotation. It may initially be quite far from center. Gently adjust the position of the lazy susan mount stage until rotation looks reasonably centered. Centering will not be perfectly consistent because the lazy susan has some play, but it is worth being close for ease of use. When centered to your satisfaction, very gently remove the objective board without moving the specimen stage or lazy susan mount. Carefully rotate the plexiglass stage so you can access the lower mounting holes, and mark them clearly.



(As above, this image shows an earlier prototype, but this step of marking stage corner holes is the same.)

18. Remove the lazy susan and set aside. Drill holes in the four locations you marked on the stage board. It's important these holes are well placed for centering, so making a hole punch divot in the center of each marked location before drilling may be helpful here. Place the lazy susan mount over the holes, then use #6 machine bolts and nuts to attach it firmly to the stage.

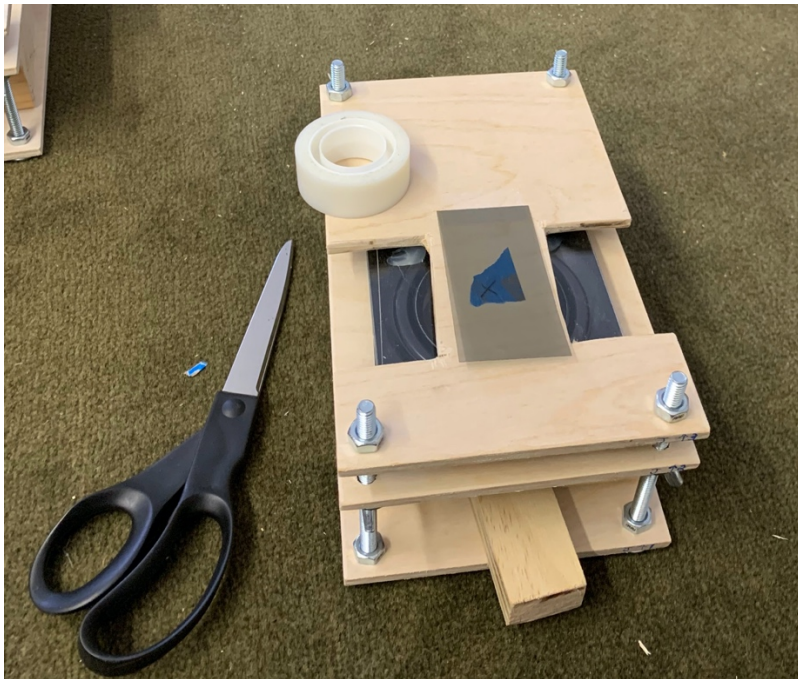


19. If you have an oscillating Dremel tool or scroll saw, it is worth trimming the top, objective board for easier stage access during use. This does not have to be precisely measured or cut to be effective, but it is important to sand the edges after trimming to reduce the risk of cuts or splinters. One way to do this is shown below: the objective lens

is covered with protective painter's tape on both sides of the board, approximate distances are marked, the board is clamped in place, and the sides are cut away to leave about 1-1.25 inches remaining in the center. This leaves enough of the board to still safely hold the weight of a camera phone, while making it easier for users to access slides on the stage.

20. Reassemble the stage and objective boards and recheck focus with the camera. Make sure the top board is reasonably close to level. Add a second nut above the top board on each bolt and tighten each pair of nuts to firmly fix the objective board in place. Unless adjustment is needed in the future (like if the specimen stage is too low and runs into the polarizer mount during focusing), you can leave the objective stage in place and use the wing nuts to raise and lower the specimen stage for focusing. (It will be necessary to remove the protective tape from the lenses before use, however.)

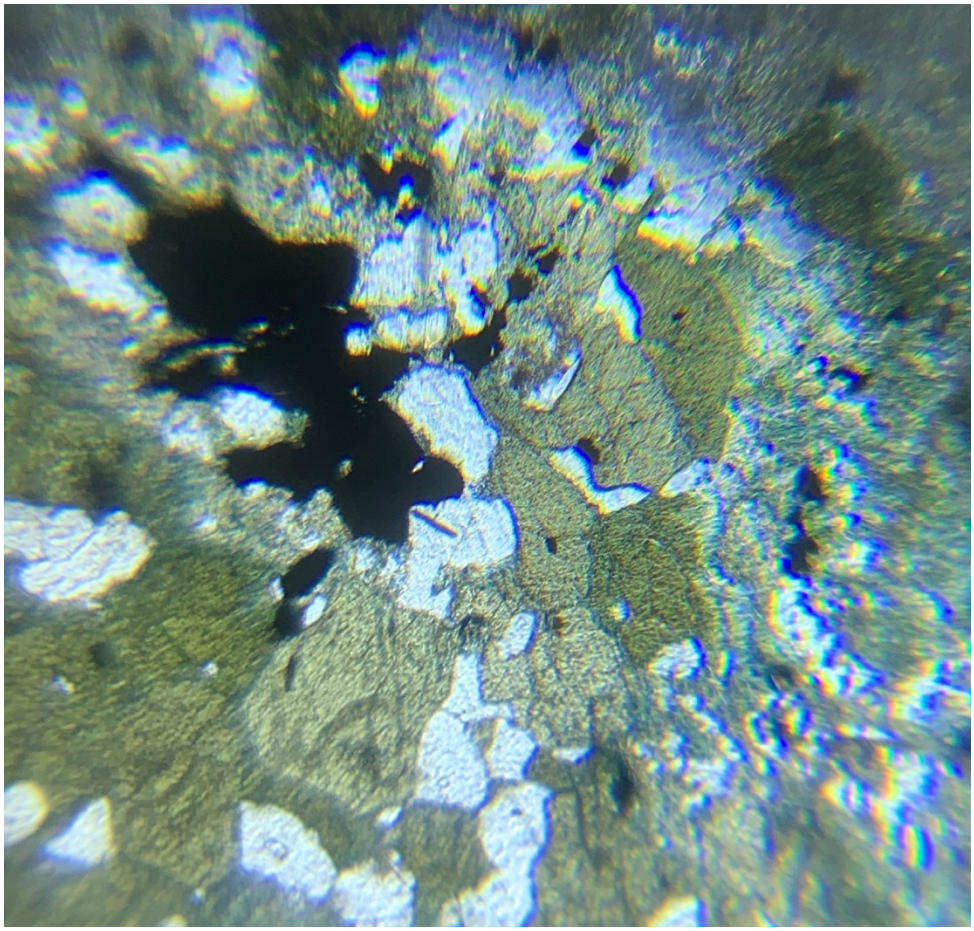
21. Finally, add the analyzer. With a fixed lower polarizer, the upper film needs to sit on top of the assembly. This means you will need to remove the phone camera to add and remove the analyzer. Check alignment with the lower film to make sure the films will achieve good cross-polarization, and then trim the film in half lengthwise, to lie along the center of the objective board.



22. Use a piece of transparent tape to attach the top piece of this film to the board in the correct orientation. Flip the film up and crease the film slightly so it will flip up and down easily without unpeeling. The tape can be replaced as needed. (NOTE: If a removal lower polarizer is being used instead, this film can be attached more permanently on the top and bottom so it does not move. This design improvement has not yet been fully tested.)

23. Finally, use your microscope! Focus will likely be the best in the center of the lens, which is not equipped for polarization so can reasonably be expected to exhibit some distortion

around the edges. The polarizers may also be slightly warped instead of perfectly flat, which may produce slightly shadowy interference figure isogyres in the field of view, but these are mostly unobtrusive when viewing a thin section.



Plane-polarized light image of an amphibolite thin section, taken during initial focusing through a single collimating lens. The camera was not yet particularly well aligned in this test, but you can see the center of the field of view reasonably well. The outer edges are distorted largely because this isn't a proper pol objective lens, and it's a low quality lens, but it should work for demonstrating the basics of how the microscope functions.