# Collection and Preparation of Thin Sections of Oriented Samples

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**ABSTRACT**

Many techniques of microstructural analysis have become available for determining the shear sense in ductilely deformed tectonites; however, these techniques require that one collect oriented samples from the field and retain the sample orientation throughout the thin-section process in order to correctly determine shear sense with respect to map structures. The trick to collecting oriented samples is having a system, or conventions, which become familiar; a system with built-in redundancies is best because it helps one minimize and correct mistakes. In this paper, I outline a method for collecting and cutting oriented samples for microstructural analysis.

**Keywords:** Field geology; geology teaching; structural geology; L-S tectonite; kinematic analysis; oriented samples; structural analysis.

In the past ten years many techniques have become available for determining shear sense in ductilely deformed tectonites (Berthé and others, 1979; Bouchez and others, 1983; Simpson and Schmid, 1984; Lister and Snoke, 1984; Simpson, 1986, among many others). These techniques require microstructural analysis; therefore, one must be able to collect oriented samples from the field and retain the sample orientation throughout the thin section process. A geologist making thin sections can mark and remark chips and sections in order to keep track of the sample orientation; however, if one is sending rock chips to a commercial laboratory for thin sectioning, one must use a method of permanently orienting the chips. Outlined below is one method of collecting and cutting oriented samples for microstructural analysis. I describe the process for L-S tectonites as these rocks are generally most useful for microstructural kinematic analysis, although the method can be modified for nonfoliated rocks.

The trick to collecting oriented samples is having a system or conventions which become familiar; a system with built-in redundancies is best because it helps one minimize mistakes and correct them when they do occur. I have found the system and conventions outlined below to be both relatively easy to follow and extremely useful.

### Collecting Samples

Typically, slabby rocks with well defined foliation and lineation are the easiest to sample and commonly the most useful for kinematic analysis. Obviously, however, the particular requirements of the project will determine the nature of the rocks to be collected. It is important to be sure that the samples collected are structurally in place, or all the effort will be for nothing. Remember, "bad data are worse than no data."

In order to uniquely orient samples, simply choose one plane of the sample to measure and mark. Rather than clutter the rock with non-systematic arrows or measurements, I rely on the structures within a sample (which I am generally concerned with anyway; in fact it is the presence of the structures that leads me to collect an oriented sample in the first place). Strike and dip uniquely orient a plane in space; if a rock is foliated, use the foliation plane to orient the sample. Measure the strike and dip of the foliation, and the trend and plunge of the mineral lineation (alignment, elongation, or stretching), and record these values.

I use the following notation:

| | |
|---|---|
| <u>AK-2</u> | (station – sample location) |
| MF = SO = N21W, 52SW | (MF = metamorphic foliation;<br>SO = sample orientation;<br>strike: north 21 degrees west;<br>dip: 52 degrees southwesterly) |
| Le = N56W, 37 | (Le = elongation lineation;<br>strike: north 56 degrees west;<br>dip: 37 degrees). |

To the left of the recorded measurements sketch the orientation of foliation and lineation as a check on the measurements; make sure that the foliation and lineation measurements are consistent with each other *and* with the structures in the field. This provides a graphic representation of the data, making it easy to skim through one's notes and to quickly detect structural consistency, or the lack thereof.

After recording the foliation and lineation, and checking the measurements for consistency, mark the sample. The sample can either be marked before or after it is freed from the outcrop. If it is marked after removal, it must be possible to put it back in place for marking. Before hammering away at the rock, it is useful to look for a sample that can be easily removed, yet has the structures of interest. One can often save much time and frustration when collecting oriented samples by spending a little extra time looking for a good sample that is easy to collect. A cold chisel (or stone chisel), which can be purchased in most hardware stores, is an extremely handy tool for collecting oriented samples.

Marking the sample consists of marking the strike and dip, the mineral lineation (if present), and "up" or "down." Using a compass, mark a strike line on the plane of the foliation (or whichever plane is chosen to orient). The strike should be the same as that recorded in one's notes. Holding the compass against the foliation plane, mark the horizontal strike line with an indelible marker. (If the rocks are wet a colored pencil or crayon works well, but be sure to go over the markings with an indelible marker when the rock has dried, otherwise markings can be lost.) Draw half an arrowhead in the general north direction (quadrants), or in the direction of strike (azimuth) in order to uniquely orient the strike line. In addition, draw a tick mid-way along the strike line in the down-dip direction (as

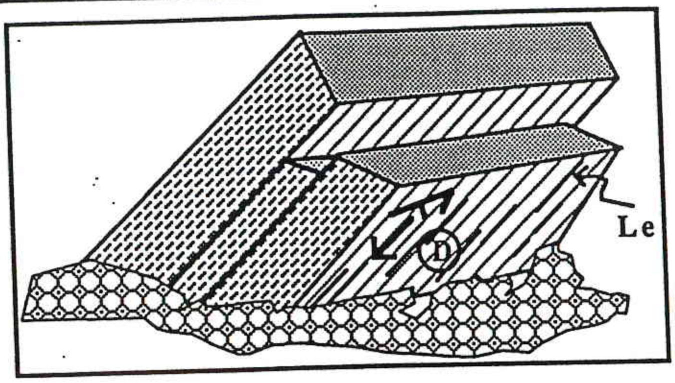


**Figure 1. Orienting the sample in the field. Bold markings are the markings drawn on the sample.**

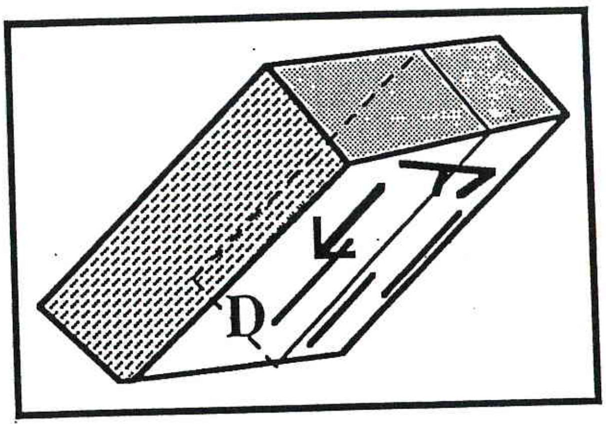


**Figure 2. Marking the motion plane, the plane perpendicular to foliation and parallel to elongation lineation.**

shown in Figure 1). The half arrowhead at the one end of the horizontal line differentiates NW from SE, or N10 from N190; the down-dip tick differentiates which way the rock dips on the strike line. Although this symbology (combined with the notes) uniquely defines the orientation of the sample, I build in a few redundancies. These are not necessary, however, if you have never made a mistake and plan to continue that trend. In addition to the strike and dip symbol, mark the mineral lineation with a full arrowhead in the plunge direction. If the lineation of the sample has a plunge of zero (that is, if Le is strike slip), draw the arrow in such a way that the arrowhead points in the general north direction, whether NW or NE. If one is conducting study of the kinematic of the tectonites, it will be necessary to note elongation lineation (Le) anyway, and marking Le in the field will make laboratory preparation easier. Also mark a "U" (for up) or a "D" (for down), depending on the facing of the surface on which the sample orientation has been marked. If the marked surface faces up, draw a "U"; if the surface faces down, draw a "D." This will also save time when the rocks are oriented for thin-section preparation.

When taking a sample note any mesoscopic- to macroscopic-scale structures, and their relationship to the sample.

## Handling Samples in the Laboratory

After oriented samples have been collected, that orientation must be preserved throughout the thin section preparation process in order to make any use of the samples. This process is straightforward if one follows a few conventions.

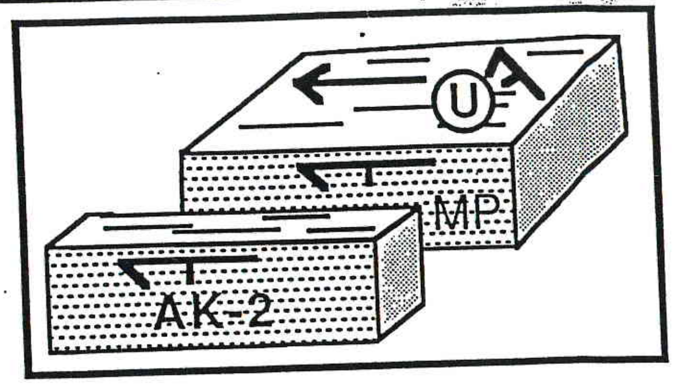


**Figure 3. Sample and sample markings for slabs cut parallel to the motion plane. The tip of the arrow points in the down plunge direction, and the tick in the down direction. Note that this symbol means something different in this context than it does in the field.**

If samples have been collected for kinematic analysis, it will probably be desirable to cut the samples parallel to the motion plane. The motion plane is that plane which contains the elongation lineation and is normal to foliation (Arthaud, 1969); this is the plane which should record shear criteria.

## Cutting and Orienting Chips Parallel to the Motion Plane

Using a marker pen draw a line around the sample marking the trace of the motion plane (Figure 2). A simple way to do this is to place a rubber-band around the samples, parallel to the mineral elongation lineation on opposite foliation faces and normal to foliation. Mark the trace of the rubber band on the sample; this is the trace of the motion plane.

Cut a slab parallel to the motion plane (Figure 3) (or have such a slab cut, being sure to get all the pieces of the rock back for further marking). Keep all the slabbed pieces together so the correct orientation can be marked on the thin-section slabs. If the rubber band was left on the sample during the cutting, the same rubber-band can be used to hold all the slices of that particular sample together.

Next, orient the sample and cut slabs such that "U" is up or "D" is down. If "U" or "D" was marked on the sample in the field, it will not be necessary to consult one's notes at this point. However, if up or down was not marked on the sample, then the field notes will have to be consulted. Use the strike and dip symbol, (with or without the lineation symbol) to orient the sample so that the up face is up. The thin-section slab can now be oriented with respect to foliation and lineation. I use the same symbol that I use in the field for sample-orientation strike and dip, however, here that symbol means something different. Draw the arrow with the tick on the cut slab so the arrowhead points in the plunge direction of lineation, and so the tick is in the down direction (Figure 3). Markings on either side of a thin-section chip should be the mirror image of one another (Figure 4). If sample lineation has a plunge of zero, draw the arrow so that the arrowhead points generally north.

The thin section chip is now uniquely oriented; however, after the thin-section has been cut and marked, one of the following methods should be used to code the chip with its orientation. Although thin-section technicians will etch the orientation of the chips on the glass slide for a small fee, mistakes are easily made. The orientation arrow can easily be destroyed by the thin sectioning process, leaving no way of checking the accuracy of the final orientation etched on the glass.

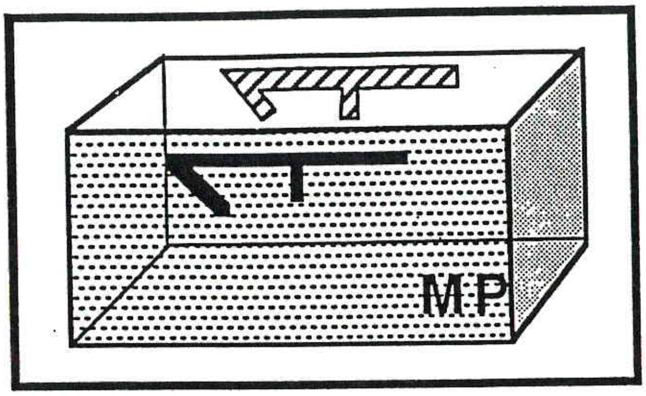


**Figure 4. Opposite sides of a slab show mirror images of the orientation arrow.**

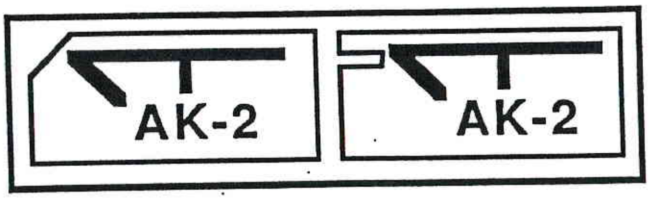


**Figure 5. Alternate methods to cut thin-section chips such that the shape serves to orient the sample. The cut in both cases is in the upper corner in the down plunge direction. Using this method automatically shows the mirror image as viewed from either side of the completed thin section.**

The two methods illustrated in Figure 5 allow the chip to be coded with its orientation in such a way that the information cannot be lost or destroyed in the thin-sectioning process. By cutting the chip to reflect the orientation arrow, the new shape of the chip serves to orient the sample. Cut the thin-section chip in either of the ways shown in Figure 5. The additional cut in both cases is in the upper corner of the chip in the plunge direction. The chip now shows the mirror image as viewed from either side or as viewed within the finished thin section. By cutting the chip in either of the ways illustrated in Figure 5, the sample will have been permanently oriented with respect to foliation and lineation. If the orientation arrow is destroyed (indelible markers are not indelible to many of the epoxies used in making thin sections), the chip remains oriented. One of the methods may be more suitable depending on internal structure and fissility. After the thin sections come back from the laboratory, the corresponding orientation arrow can be etched on the glass slide; but it is not necessary to do this. The shape of the chip, and therefore the shape of the rock thin section, is easily viewed.

After the thin sections are completed, it is easy to see the inscribed arrow or the cut marks in the petrographic microscope. Different microscopes transpose images differently, so it is helpful to see the marker (arrow or cut mark) transposed in the same way that the rock fabric/microstructures are viewed in the sample. Examine the slide and interpret shear criteria relative to the arrow or markings (Figure 6). Remember that the arrow or cut marks point in the plunge direction so one can simply record down-plunge (apparent normal displacement) or up-plunge (apparent reverse displacement) shear sense. At this point, and really *only* at this point, is it necessary to go back to the field notes and find out what the kinematic interpretation means in terms of the regional geology.

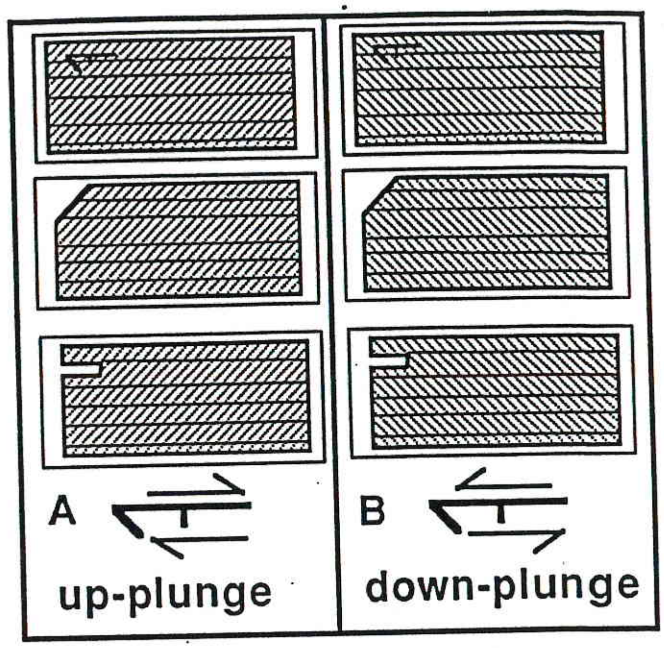


**Figure 6. Fabric asymmetry and interpretation; (a) down-plunge interpretation; (b) up-plunge interpretation.**

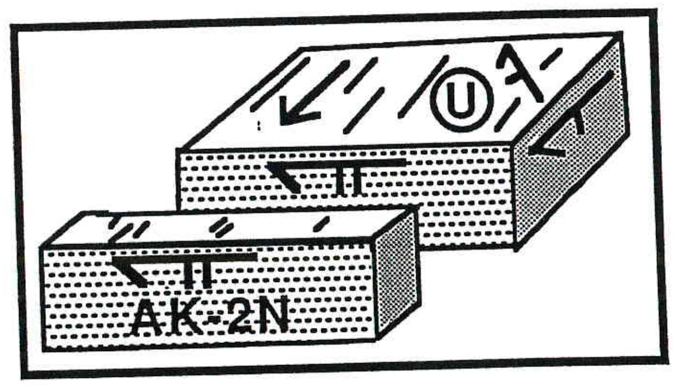


**Figure 7. Sample and sample markings for slabs cut perpendicular to foliation and lineation. Mark the sample with the double ticked orientation arrow. The tip of the arrow points in the down-dip direction, and the double tick in the down direction. An "N" after the sample number indicates that the chip and thin section are cut in the plane normal to foliation and lineation.**

**Cutting and Orienting Chips Normal to Le and Foliation.**

Although most microstructural kinematic indicators are recorded in the motion plane of L-S tectonites, one may be interested in measuring strain or crystallographic fabrics in the plane perpendicular to the motion plane and Le. In order to orient thin-section chips in this plane, collect the sample in the manner outlined above and slab the rock perpendicular to foliation and lineation (Figure 7). Orient the sample pieces such that "U" is up and/or "D" is down. Mark an orientation arrow on the slab so that the half arrowhead points in the dip direction of the cut face; mark two ticks on the down-side of the arrow (Figure 7); the vectors in the motion-plane face and in this face should add together to parallel the direction of dip. The two ticks on the orientation arrow indicate that this slab is cut from the plane perpendicular to foliation and lineation. Also label the chip with an "N" following the sample number

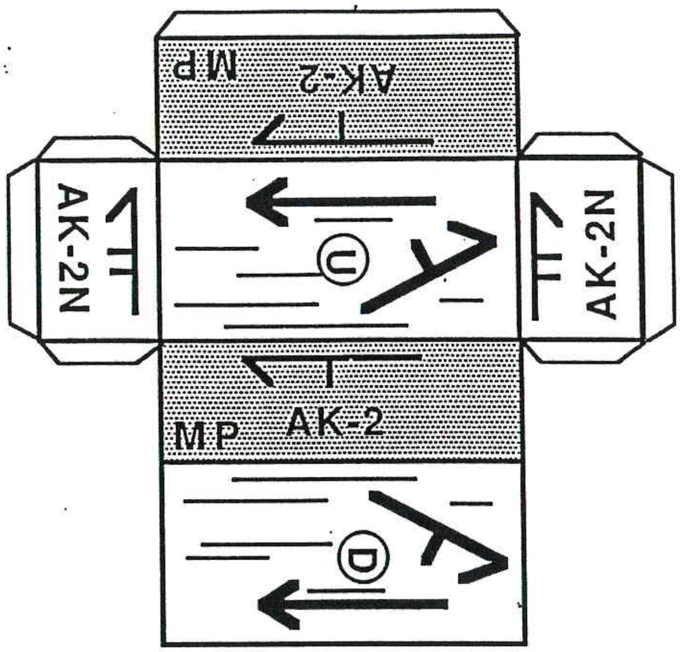


**Figure 8. Fold-up of a three-dimensional orientation reference box. Symbols are the same as in the text and other figures; MP = motion plane.**

to indicate that the section is cut in the plane *normal* to foliation and lineation.

It may be helpful to make yourself a three-dimensional model of a typical L-S tectonite sample with the specific orientations markings described here (Figure 8). I use an old slide box marked with an indelible marker. I keep it handy when I am slabbing rocks for thin sections, when I am interpreting my thin sections, and when I am rotating crystallographic fabric data measured in the motion plane and in the plane normal to foliation and lineation into a single plane.

The techniques of modern microstructural and kinematic analysis allow interpretation of the movement history of ductile tectonites. Such studies add powerful constraints to regional tectonic models; however, one must be sure that sample orientations are correctly recorded and preserved throughout the analysis. Obviously, if the sample orientations are incorrect, then the kinematic analysis will be incorrect, and the study would have been better left undone.

**Acknowledgements**

Inquiries of students and colleagues who patiently listened to me discuss the value of kinematic analysis on several occasions in the field inspired me to write this article. I thank all those friends who were brave enough to ask that one "stupid question": 'I can see the value of kinematic analysis and oriented sample collection, *but how do I collect oriented samples, and what do I do with them after I have collected them?*' Structural geologists using techniques of kinematic analysis often forget that most geologists (including themselves) were never taught how to collect oriented samples. Furthermore, we've made lots of mistakes developing conventions. John Goodge, Gail Sease, and Sue Smerka reviewed early versions of this paper and provided many helpful comments. Hansen's research is supported by NSF EAR 8715911 and PRF 2116-G2.

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**About the Author**

Vicki Hansen is an assistant professor of geology at Southern Methodist University. Her research interests include understanding tectonic processes along and within the deep-seated part of convergent plate margins.

## Food for Thought

Neptunism and vulcanism were both theories of epic scale, and yet their names give a false impression of direct confrontation – as the power of water against the fury of fire. The central tenet of neptunism was that the Creation of the Earth was directly recorded in the configuration of the rocks; of vulcanism that the configuration of the rocks provided insight only into the operation of the process of the Earth. Thus, viewed as the focus of wide-ranging opinion, an inclination towards neptunism was encouraged by studying mineralogy and reading Genesis; a tilt towards vulcanism by observing, and reading with an innocent heart, the landscape of rocks.

Robert Muir Wood, 1985, *The dark side of the earth*: London, George Allen and Unwin, 246 p. (from p. 4).