Clastic sedimentary rocks are composed of grains that have been weathered from pre-existing rocks. The chemical weathering processes of hydrolysis, oxidation, and dissolution act on sediments, destroying those minerals that are most reactive, and forming new minerals that are stable at surface conditions: most halides and sulfates will dissolve; pyrite will form hydroxy-oxides such as limonite; unstable silicates will form clays. Minerals that are susceptible to physical weathering (i.e., minerals that are soft or cleavable) will be reduced in size during transport, and so may only be identified under the microscope.

Quartz is a common rock-forming mineral, and resistant to both chemical and physical weathering. Accordingly, it is a common constituent of clastic sedimentary rocks. Feldspars are relatively stable in the surface environment, with potassium feldspars being more resistant to chemical weathering than plagioclase. Mafic minerals readily weather to form clays and iron hydroxy-oxides, and so are uncommon in sedimentary rocks. Thus the most important minerals in clastic sedimentary rocks are quartz, potassium feldspar (microcline and orthoclase), plagioclase, clays, and oxides/hydroxy-oxides (hematite, limonite, goethite). Percentages of quartz, feldspar, and clay are used to classify most clastic sedimentary rocks (sandstones, siltstones, claystones).
QUARTZ

Examine hand samples QUARTZ 1, QUARTZ 2, QUARTZ 3, and CHERT 1. What physical properties are common both microcrystalline (e.g., chert, flint) and crystalline forms of quartz?

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What hand-sample properties allow you to distinguish quartz and chert from each other?

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Examine the standard thin-sections QUARTZ and QUARTZ-AGATE. Determine the optical properties of quartz sample and complete a sample description form.

Examine the standard thin-sections QUARTZ-CHERT. Compare this sample of chert (micro-crystalline quartz) with the quartz samples that you just studied. How is chert distinct from quartz in thin-section?

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Examine thin-section QUARTZ-UND. This thin section contains quartz that has been deformed, and exhibits what is called undulose extinction. That is, the grain does not go extinct all at once, but rather extinction sweeps across the grain. Undulose extinction is common in quartz. Note that quartz grains that exhibit undulose extinction may not yield uniaxial interference figures because the crystal lattice has been disrupted by deformation.
PLAGIOCLASE

Plagioclase is a group of feldspar minerals that have complete solid solution from NaAlSi$_3$O$_8$ (albite) to CaAl$_2$Si$_2$O$_8$ (anorthite). Na-rich plagioclase tends to be white in hands-sample, whereas Ca-rich plagioclase tends to be dark grey. The coupled substitution of Na-Si for Ca-Al in plagioclase also has profound effects upon the optical properties of these minerals. The most distinctive changes are reversal of optic sign, and the characteristics of twinning.

**Twinning** is the intergrowth of two or more crystals in a symmetrical fashion by the sharing of lattice points in adjacent crystals. In plagioclase, the most common twins are planar and repeated (polysynthetic twinning), resulting in the striations that are characteristic of plagioclase in hand-sample and the striped appearance of plagioclase in thin-section under cross-polarized light. This type of twin is referred to as an albite twin because it is so common in plagioclase. Another common twin in plagioclase involves the intergrowth of two crystals that are oriented 180° with respect to each other. This twin that separates the mineral into two distinct domains is called a Carlsbad twin.

Twinning tends to be better developed in Ca-plagioclase minerals, and the extinction angle of the twins varies systematically with composition. This systematic variation in optical properties allows a petrographer to determine the composition of plagioclase using a petrographic microscope. The Michel-Levy method for determining plagioclase composition is based on the extinction angle of sets of albite twins in appropriately oriented mineral grains.
To determine plagioclase composition using the Michel-Levy method, follow the procedure described below:

1. Find a plagioclase grain that displays only albite twins
2. Rotate the stage so that the twins run N-S. If all twins have approximately the same interference color, then this grain can be used. If there is a significant difference in interference colors between sets of twins then return to step 1.
3. Record the position of the stage in number of degrees
4. Rotate the stage clockwise until one set of twins is extinct. Record the position of the stage in number of degrees, and the number of degrees that you rotated your stage from step 3.
5. Rotate the stage counterclockwise until the other set of twins is extinct. Record the position of the stage in number of degrees, and the number of degrees that you rotated your stage from step 3.
6. The two rotation angles should be within 4 degrees. If its is, then average the two angles. If not, discard the result and return to step one.
7. Repeat this procedure three times. Take the highest average rotation angle and use the following graph to determine the composition of plagioclase. Note that albite cannot be distinguished from low-An andesine using this method.
Examine plagioclase hand-samples ALBITE, 69 OLIGOCLASE, and LABRADORITE. What physical properties are common to all three plagioclase minerals?
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__________________________________________________________________________

What physical properties allow you to distinguish these plagioclase minerals from each other?
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Examine thin-section ANORTHITE. Determine the optical properties of this plagioclase mineral, and complete a sample description form.

Examine the plagioclase in thin-section PLAG 1. Use the Michel-Levy method to determine the composition of the plagioclase in this rock

<table>
<thead>
<tr>
<th>Position of Stage (degrees)</th>
<th>Stage Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Position when Twins</td>
<td>Rotation Angle</td>
</tr>
<tr>
<td>Are N-S</td>
<td>To Set 1 Extinction</td>
</tr>
<tr>
<td>Stage Position when Twin Set 1 Is Extinct</td>
<td>Rotation Angle To Set 2 Extinction</td>
</tr>
<tr>
<td>Stage Position when Twin Set 2 Is Extinct</td>
<td></td>
</tr>
</tbody>
</table>

Maximum Average Rotation Angle: __________

Plagioclase Composition: __________
ALKALI FELDSPARS

Microcline and orthoclase are *polymorphs*. That is, they have the same composition but different crystal structure. In hand sample, it is not usually possible to distinguish between these two minerals. In thin section, the two can be distinguished based upon their twinning.

Under cross-polarized light, microcline (Sample 44 5078) displays two sets of polysynthetic twins at right angles that form a distinctive cross-hatched pattern that is referred to as *tartan twinning* (photo to right). Orthoclase displays either no twinning, or simple *Carlsbad twinning* in which the crystal is divided in half by a twin plane. Orthoclase occurs most commonly in volcanic rocks.

Examine hand-samples MICROCLINE 1, MICROCLINE 2 (Amazonite), and ORTHOCLASE. What physical properties are common to all three potassium feldspar minerals?

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What physical properties allow you to differentiate plagioclase from potassium feldspar?

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Examine sample the standard thin section for MICROCLINE. Determine the optical properties of microcline, and complete a sample description form.