Lunar thin-sections
STFC Lunar Samples Package

A-Level

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Introduction

This booklet provides information on the use of petrological thin-sections and petrographic descriptions on the thin-sections provided with the Lunar Samples Package. These notes are intended for the teachers of A-level geology students as an aid for preparing practicals on the lunar rocks.

The petrology sheets show a plane polarised light image (upper) and a crossed polarised light image (lower) of the same view of each thin-section. They provide a short description of the specimen and the expected petrogenesis. The field of view of images is 0.4 mm.

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How to use the petrological thin-sections

This section is provided to give an overview of how to use the thin sections of lunar rock accompanying the Lunar Samples Package and is intended for teachers without geology experience who would like to make use of the thin-sections.

“Do”s and “Don't”s.

- **Do** use a petrological microscope (or at the very least a microscope with a polarised light source).
- **Do not touch the upper surface of the thin section** (these sections do not have cover slips to allow the use of reflected light).
- **Take care not to drop the specimen**. These thin-sections are easily breakable and are irreplaceable. Younger students should be carefully supervised.

What are thin-sections?

Petrological thin-sections are slices of rock that have been polished on both sides so they are around 30 millionths of a metre thick and can transmit light. Thin sections are used to identify the minerals and textures (the spatial relationships between the minerals) of rocks and are still an important tool used in the modern scientific investigation of rocks. The textures of rocks seen in thin-section can provide important information on the formation of the rock. In some cases they allow us to deduce such information as the rate at which a lava cooled or the sequence in which the minerals crystallised. In this section some simple aspects of the procedures used are described.

Plane polarised and crossed polarised light

Petrological microscopes are fitted with two polarisers to allow thin-sections to be viewed in plane polarised or cross polarised light. In plane polarised light (PPL) only the polariser below the level of the microscope stage is inserted. The light that passes through this stage is polarised so that it vibrates in only one direction. In crossed polarised light (XPL) the second polariser (called the analyser), located above the thin-section, is inserted. The analyser only allows light vibrating at 90° to the original polariser to pass through. It is only because light is changed by passing through minerals that any light passes through the analyser.

Three types of mineral can be identified depending on how they behave in PPL and XPL…

- **Opaque minerals**
  These are minerals that do not transmit light and appear dark in PPL and XPL. The oxides of iron are generally opaque.
- **Isotropic minerals**
  These are minerals that do transmit light but do not change the polarised light that passes through them. Isotropic minerals appear dark in XPL and have cubic symmetry.
- **Anisotropic minerals**
  These are minerals in which polarised light is changed on passing through them. Anisotropic minerals, depending on their orientation, are not dark in XPL and show interference (birefringence) colours. Polarised light passing through a mineral is split

into two rays of light each vibrating at 90° to each other, the directions depending on the crystal structure. Since anisotropic minerals have different refractive indexes in different directions each ray travels at a different velocity. When the rays encounter the second polariser they recombine into one polarised ray of light, however, interference between the now different rays changes the colour of the light. The colours shown by an anisotropic mineral change with its orientation in the thin-section (as the microscope stage is changed) and with mineral species.

The properties of minerals in thin-section

The following describes some of the important properties of minerals that can be determined in thin-section that can be used at an elementary level with the specimens accompanying the Lunar Sample Package to identify minerals.

Properties in plane polarised light

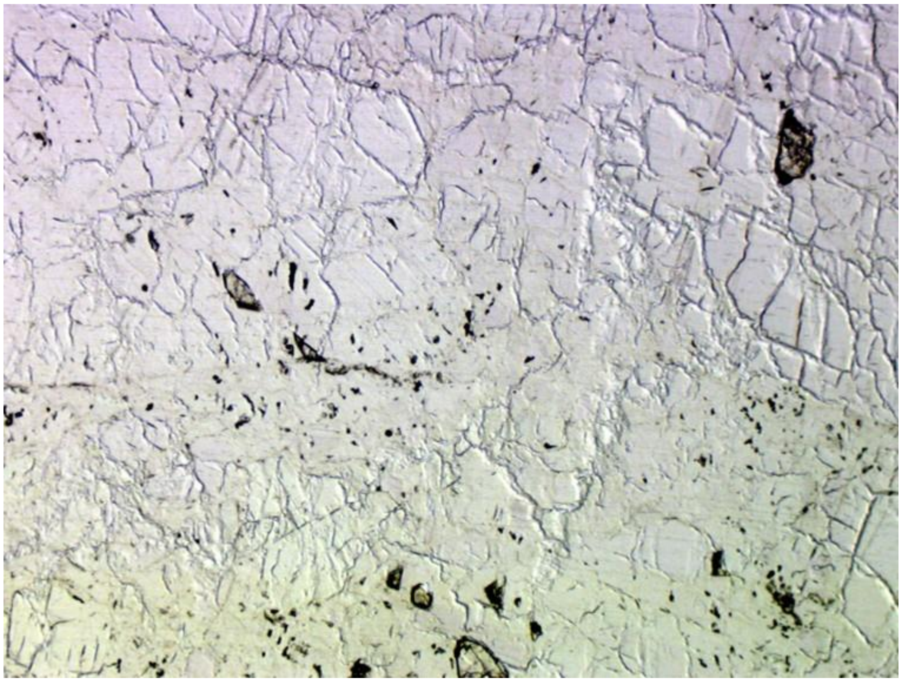
(1) **Colour**. Some minerals are coloured in plane polarised light. In the Lunar Samples Package some of the basalt thin-sections have Ti-rich augites (a pyroxene mineral) that are pink to orange in colour.
(2) **Relief**. The visibility of the outline and surface of a mineral is known as its relief. Minerals that appear to stand out from the section have a high relief. Minerals with a very different refractive index from the mounting medium (the glue that holds the specimen of the slide) have a high relief. In the Lunar Samples Package minerals such as olivine and pyroxene have higher relief than minerals such as plagioclase.
(3) **Crystal shape**. The shapes of crystals in thin-section can help in the identification of minerals. In the Lunar Samples Package many of the plagioclase crystals appear to be elongate rectangles in section (these are called laths), whereas ilmenites appear to be rhombs. Some of the ilmenites also have holes and are termed skeletal, these kinds of crystals are characteristic of rapid cooling. In the breccias and the regolith some crystals have irregular shapes that indicate they have been fractured.
(4) **Cleavage**. Planes of fracture in minerals are known as cleavage. In PPL the planes of cleavage can be seen as straight lines on the thin section. In the LSP pyroxenes and olivines can sometimes be distinguished by their cleavage. Olivines have only one set of cleavage whereas pyroxenes have two which in some orientations can be seen cross-cutting each other.
(5) **Opaque minerals**. In PPL, black shapes are the opaque minerals that do not transmit light. In the Lunar Samples Package these are often ilmenite ($FeTiO_3$).

Properties in crossed polarised light

(1) **Birefringence colours.** The colours of minerals in XPL are caused by the interference of transmitted light. In the Lunar Samples Package olivine and pyroxene minerals have "higher" colours (reds, greens and blues) than plagioclase feldspar (grey and white)
(2) **Extinction.** In XPL, as the microscope stage is rotated the minerals become darker and eventually go black. This is termed extinction and occurs when the vibration directions of light in the mineral line up with the polariser and analyser directions (these like the vibration directions in the mineral are at 90° to each other). The extinction directions are significant since they reflect the underlying atomic structure of the mineral.

(3) **Twinning**. Some minerals display a defect of growth called twinning where the crystal appears to be reflected across a plane. The atomic structure of the mineral is also reflected across the twin plane. In the LSP plagioclase feldspar crystals are often twinned and in XPL have black and white stripes. These are known as polysynthetic or albite twins and are characteristic of this mineral.

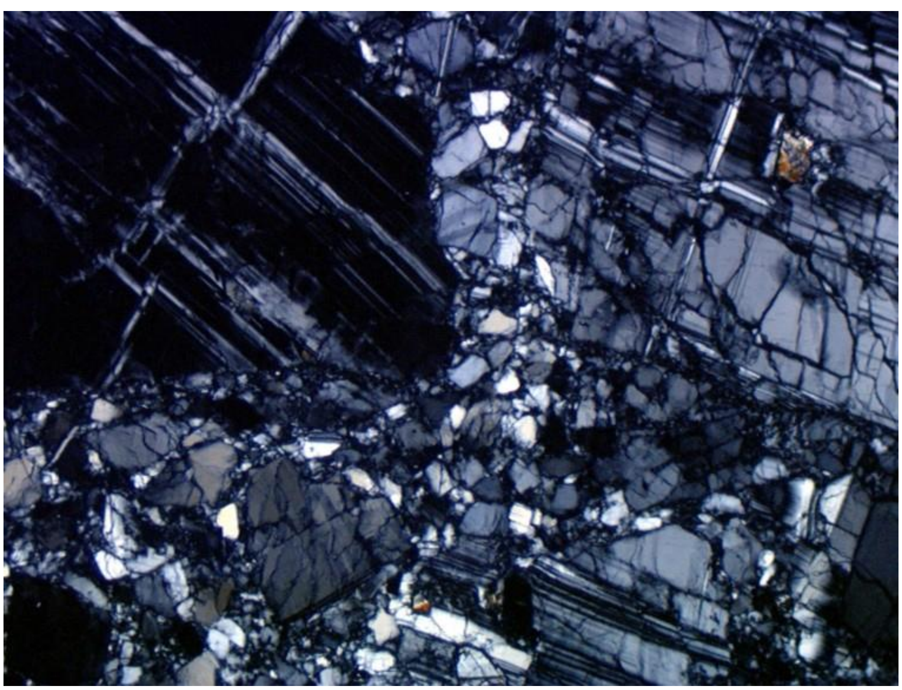
(4) **Isotropic minerals.** In XPL isotropic minerals appear opaque (black) but they transmit light in PPL. Cubic minerals and glass are isotropic. In the LSP the orange glasses are isotropic, inserting the analyser makes them go black.

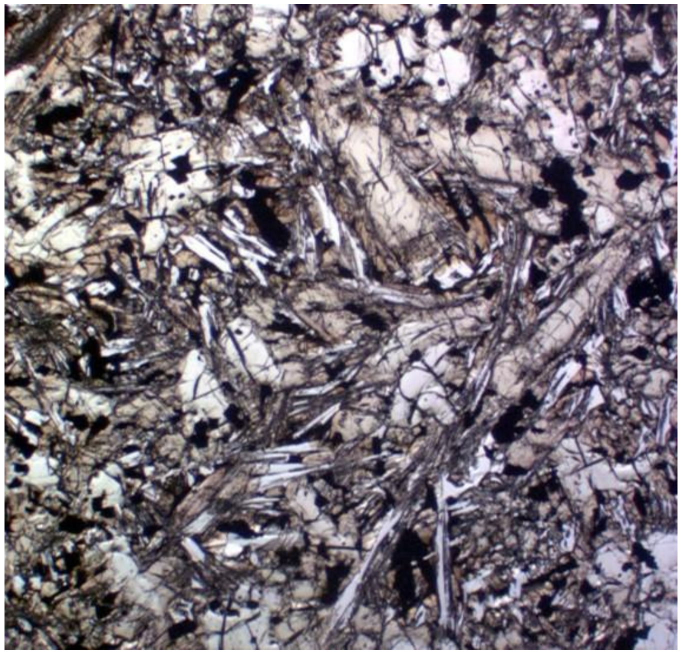


Anorthosite cataclasite (Sample 60025)

Description: A monomict breccia containing only feldspar and pyroxene clasts. A fragment of the lunar highlands.
Location: Descartes Highlands.
Mission: Apollo 16.
Age: 4440 million years.

Petrogenesis: This breccia formed from repeated impacts into the lunar highlands anorthosite crust. Impact shock is recorded by the kinked twinning of many of the plagioclase.

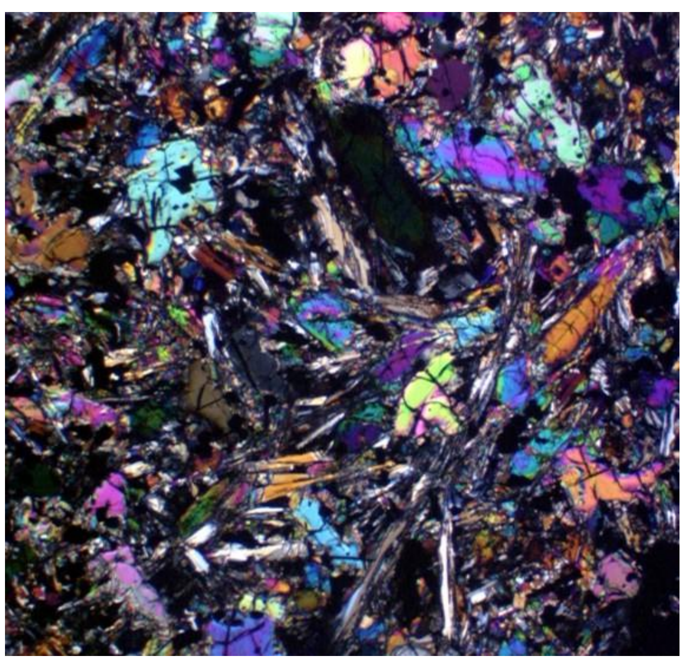


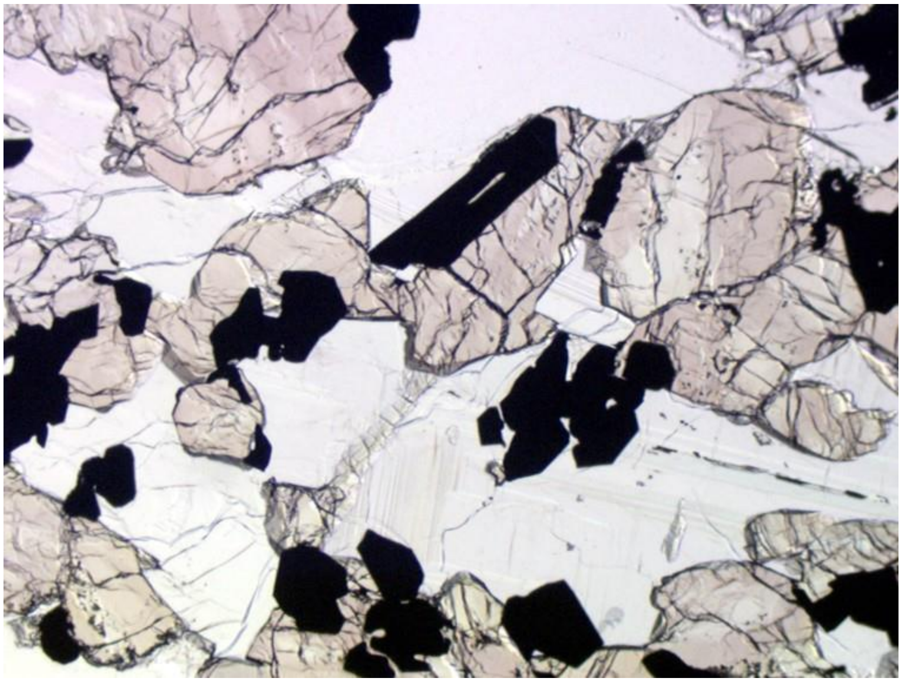


Low-Ti mare basalt (Sample 12002)

Description: Medium-grained, porphyritic basalt containing phenocrysts of colourless olivine and red-brown olivine in a groundmass of intergrown plagioclase and pyroxene.
Location: Oceanus Procellarum
Mission: Apollo 12.
Age: 3150-3350 million years.

Petrogenesis: The texture of the groundmass of this basalt and the compositions of the pyroxenes suggests rapid cooling. This basalt probably formed from the eruption of magma from ~300 km depth in the Moon.

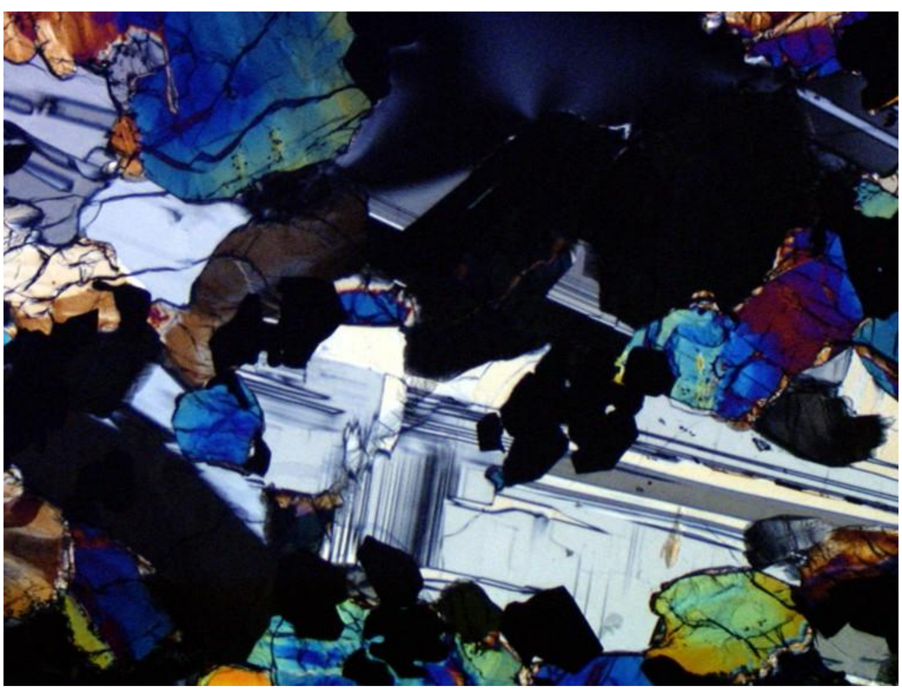


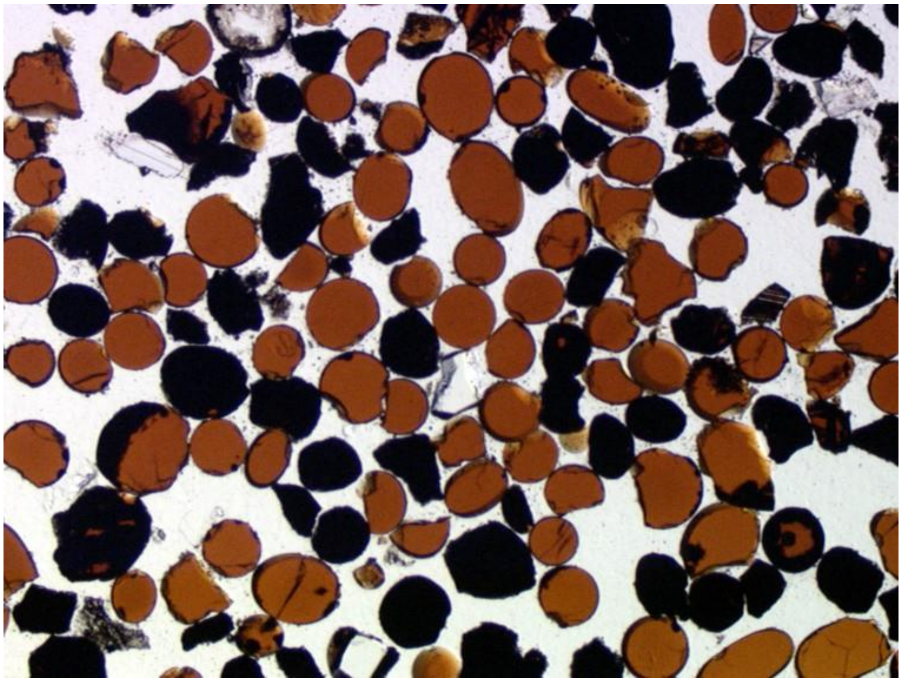


High-Ti mare basalt (Sample 17017)

Description: A vesicular, medium-grained basalt with large pyroxene phenocrysts enclosing plagioclase, olivine, later pyroxene and ilmenite.
Location: Taurus-Littrow Valley.
Mission: Apollo 17.
Age: 3700 million years.

Petrogenesis: This basalt has cooled quickly on eruption from a magma that was generated by melting of the Moon's mantle at a depth of 150 km.

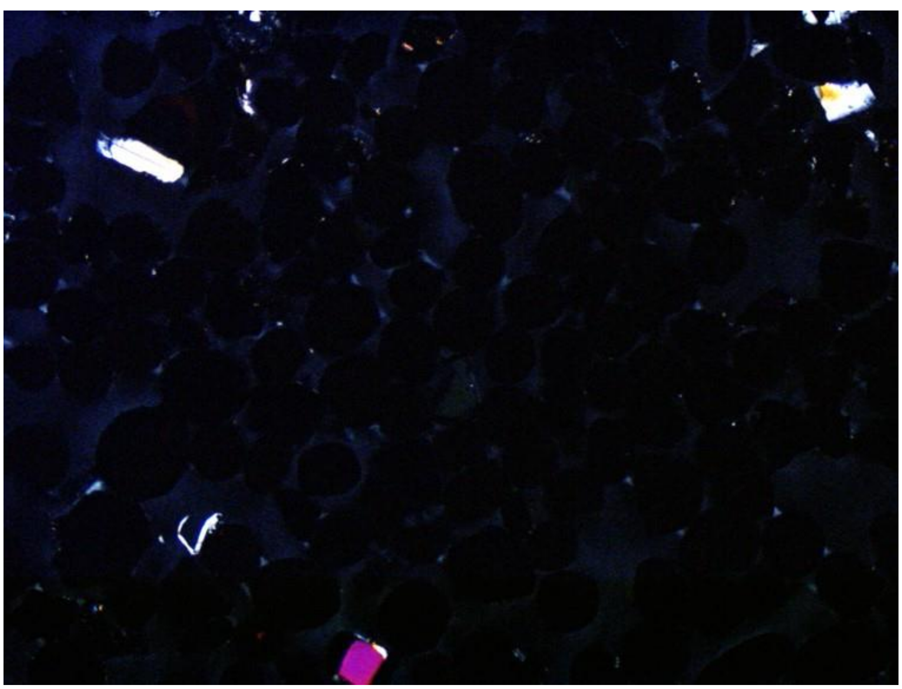


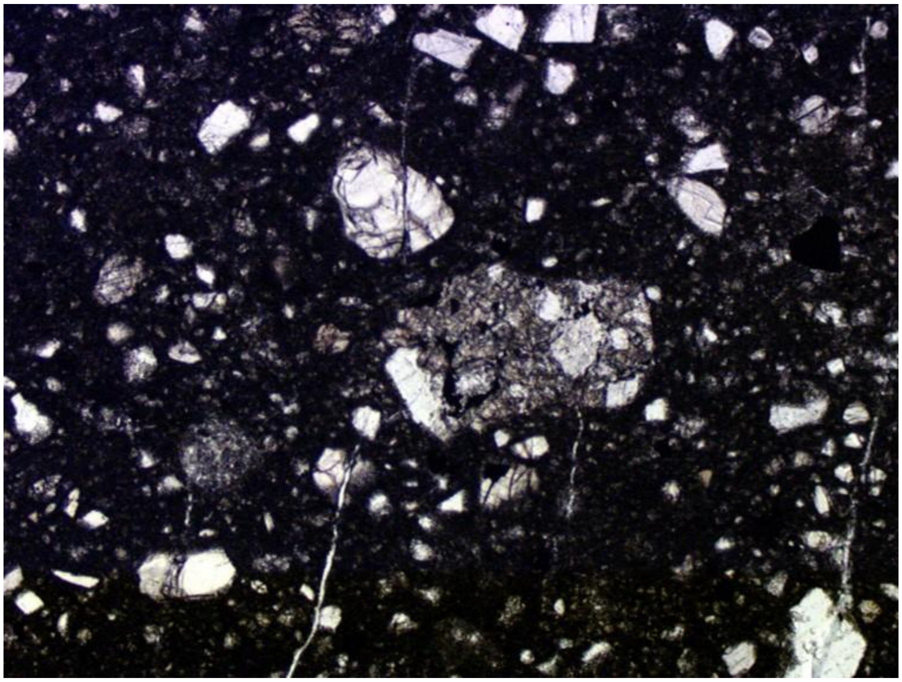


Orange soil (Sample 74220)

Description: A regolith soil containing orange glass spheres.
Location: Taurus-Littrow Valley.
Mission: Apollo 17.
Age: 3480 million years.

Petrogenesis: The orange glass spheres in this soil are thought to be volcanic in origin because of their high contents of volatile components. Some of the spheres have crystallised and there are some small fragments of mare basalt.

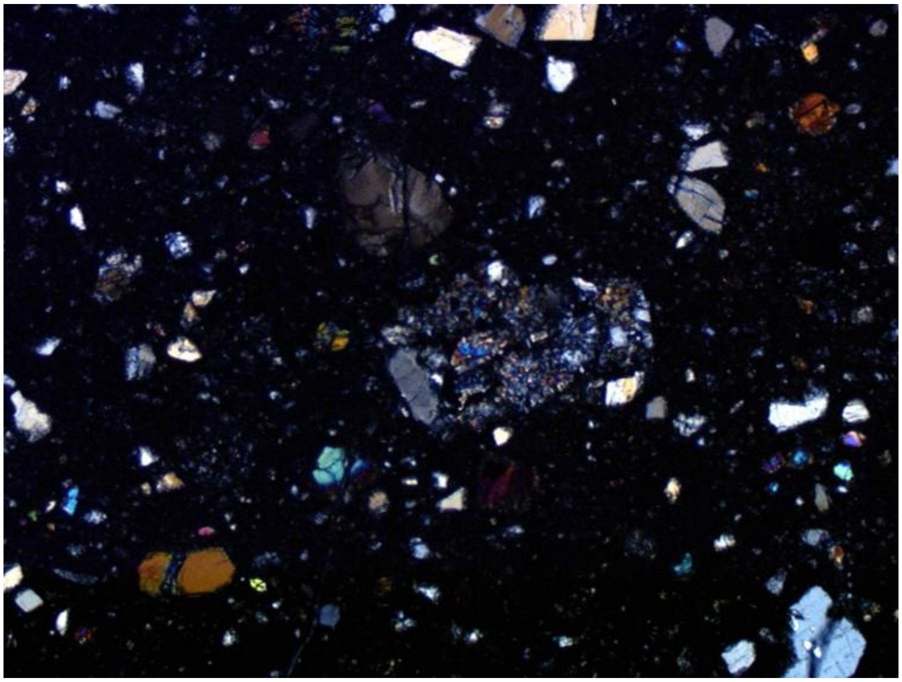


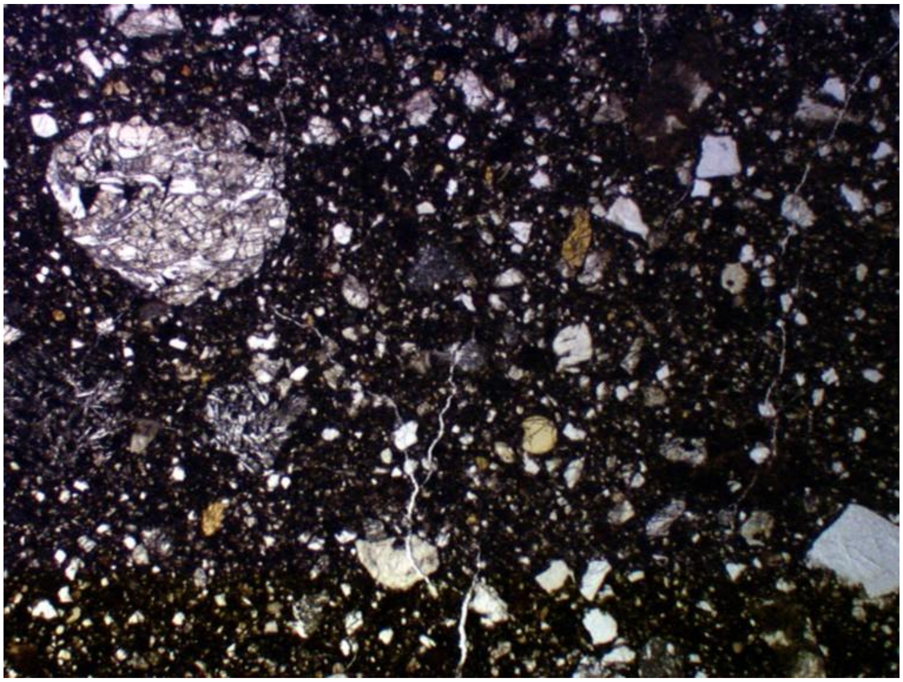


Polymict breccia (Sample 14305)

Description: A clast-rich, polymict breccia with a fine-grained recrystallised matrix. The rock contains abundant mineral and lithic (rock fragments).
Location: Fra Mauro Formation.
Mission: Apollo 14.
Age: 3820 million years (probably formed by the Imbrium event).

Petrogenesis: Since the breccia contains clasts of microbreccia several impacts are required. The last impact melted the matrix but did not melt the clasts.

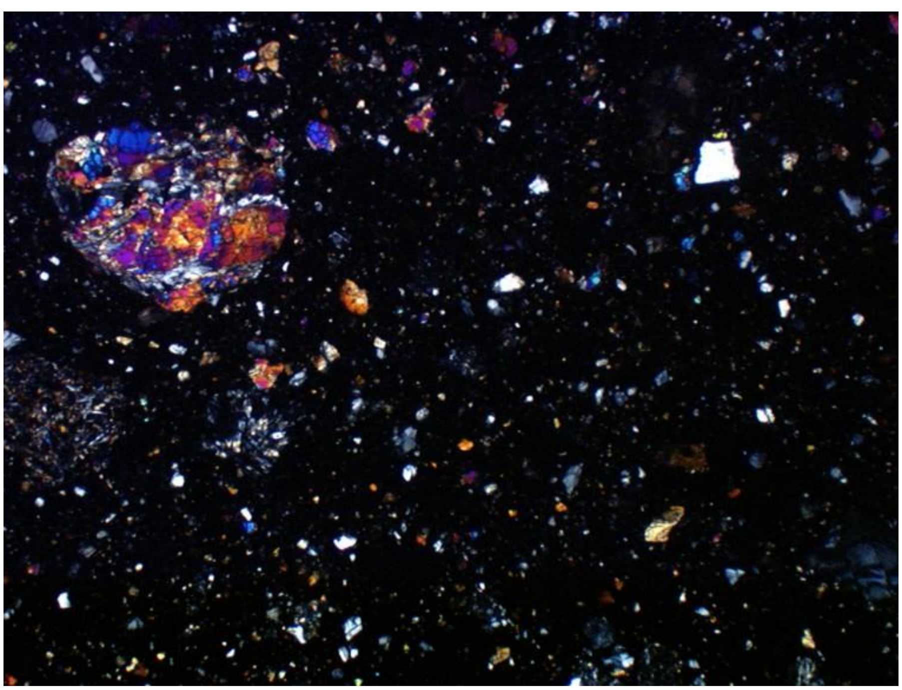


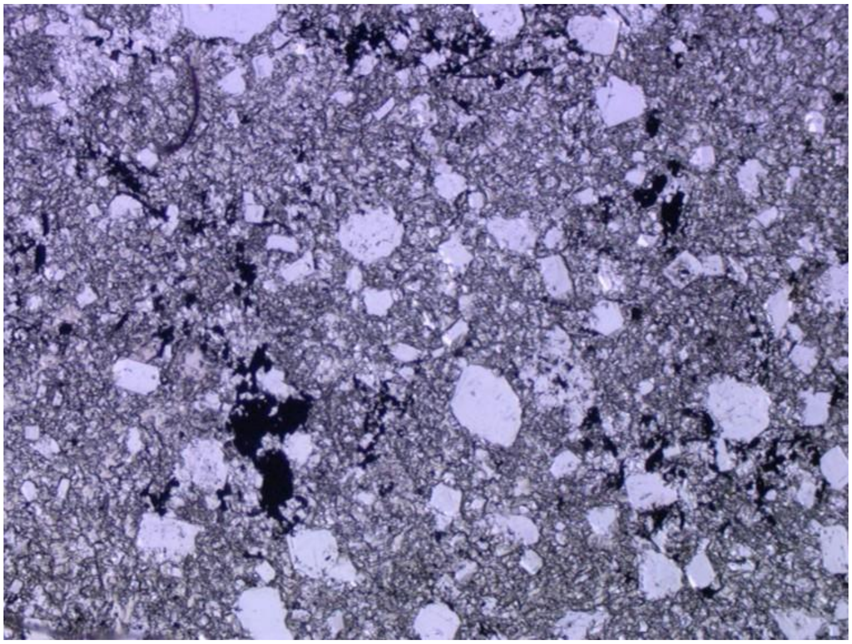


Regolith breccia (Sample 15229)

Description: A clast-rich breccia containing glass clasts (including impact melt spherules), mineral fragments and lithic clasts in a brown-glass matrix.
Location: Apennine Region.
Mission: Apollo 15.
Age: Younger than 3200 million years.

Petrogenesis: This breccia probably formed from lunar regolith since it contains impact spherules.

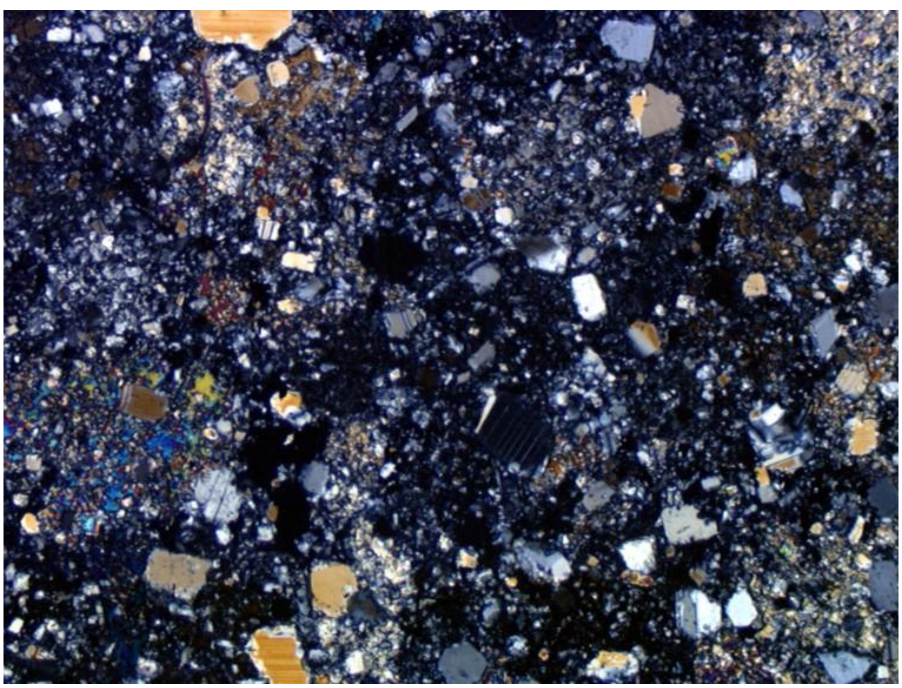


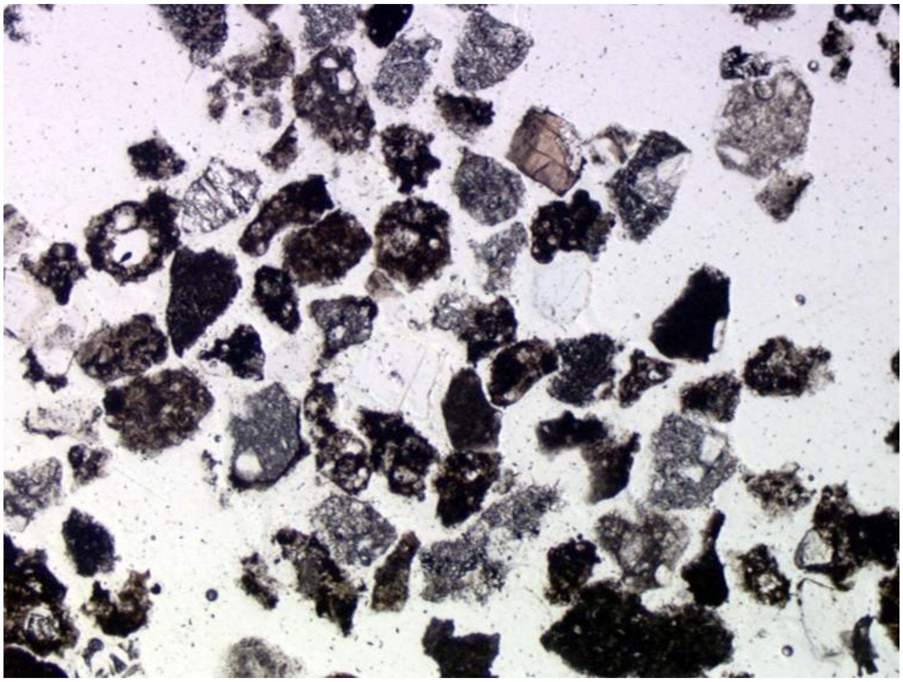


Impact-melt breccia (Sample 60015)

Description: A breccia containing clasts of minerals and lithic fragments from highlands rocks with a igneous matrix consisting of poikilitic pyroxene and plagioclase.
Location: Descartes Highlands.
Mission: Apollo 16.
Age: 3930 million years.

Petrogenesis: This breccia formed from an impact into the lunar highlands in which solid fragments of minerals and rock became mixed with hot magma generated in the impact. Some of the clasts have been partially dissolved by the magma.

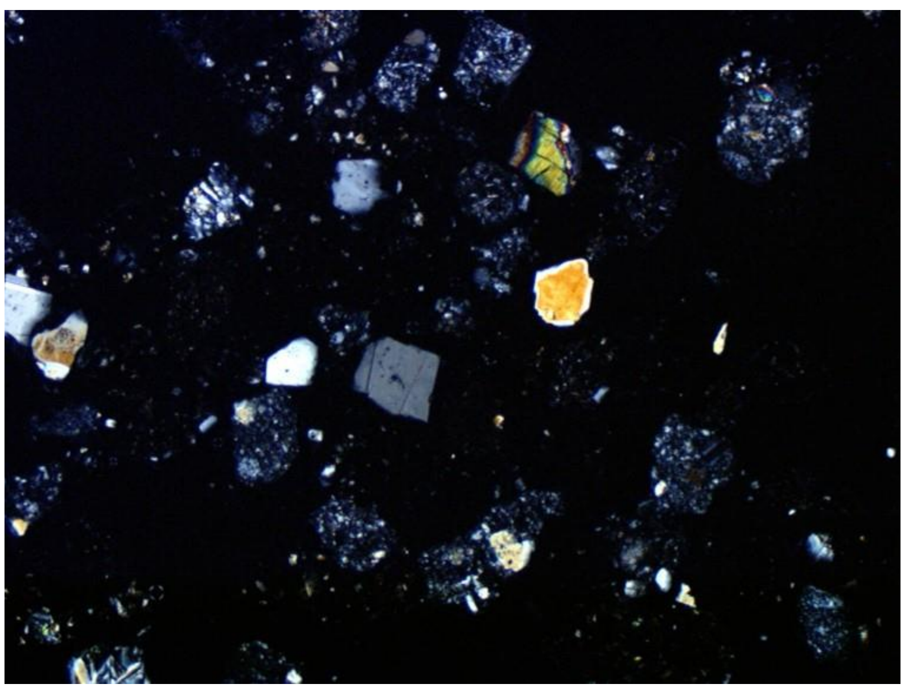


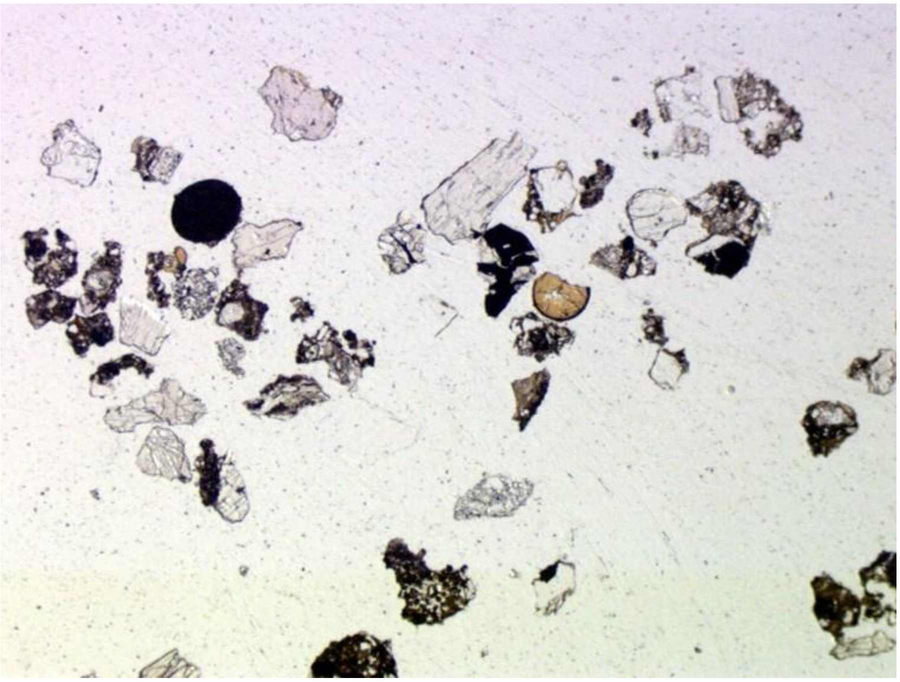


Mature highlands regolith (Sample 68501)

Description: Regolith soil consisting mainly of fragments of highlands rocks, impact-produced glass and agglutinates.
Location: Descartes Highlands.
Mission: Apollo 16.

Petrogenesis: Regolith forms from the fine-grained debris of numerous large and small impacts. Agglutinates in the soil form by melting due to the continual bombardment of micrometeoroids with the Moon's surface.

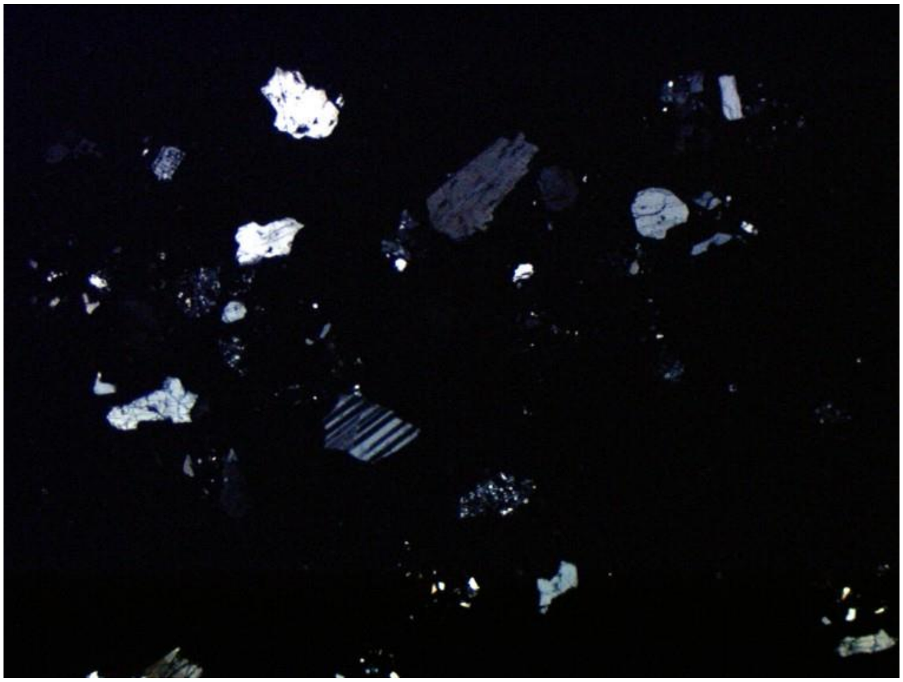


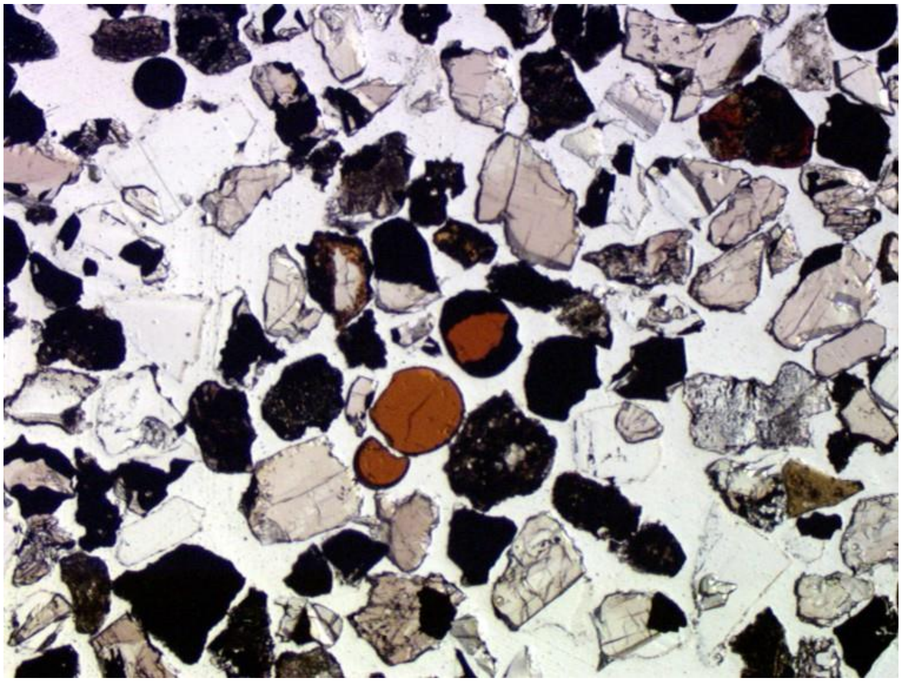


Mature mare regolith (Sample 70181)

Description: A regolith soil containing fragments of high-Ti mare basalts, agglutinates and orange glass spheres.
Location: Taurus-Littrow Valley.
Mission: Apollo 17.

Petrogenesis: Regolith forms from the fine-grained debris of numerous large and small impacts. Agglutinates in the soil form by melting due to the continual bombardment of micrometeoroids with the Moon's surface.





Mature mare regolith (Sample 71061)

Description: A regolith soil containing fragments of high-Ti mare basalts, agglutinates and orange glass spheres.
Location: Taurus-Littrow Valley.
Mission: Apollo 17.

Petrogenesis: Regolith forms from the fine-grained debris of numerous large and small impacts. Agglutinates in the soil form by melting due to the continual bombardment of micrometeoroids with the Moon's surface.