This is an eruption of Kilauea Volcano, Hawaii. The lava is erupting from vents under a lava lake, and lava flows pour from the lake downhill toward the sea. Because of the different sizes and thicknesses of the lava and underground magma in different places, it can cool and harden at different rates. For a given magma type (basalt, andesite, or rhyolite), longer cooling times (same as slower cooling rates) generally result in larger grains in the final solid rock.

All thin section photos in this presentation are © Kurt Hollocher. They may be freely used and copied for educational, non-commercial purposes.
A homogeneous magma (RED) is a liquid rock at high temperature. Entirely liquid basalt magmas are generally at ~1200°C. Entirely liquid andesite magmas, which are richer in silica and potassium and poorer in iron and magnesium, occur at temperatures of ~1050°C. Entirely liquid rhyolite magmas, highest in silica and potassium and lowest in calcium, iron, and magnesium, occur at temperatures of ~900°C.

If cooled quickly enough, magmas can quench to a glass (TAN). For basalts, cooling must take place in seconds. For andesites, minutes to hours. For rhyolites, days to weeks. The more viscous silica-rich liquids take longer for crystals to start growing, and the crystals that start take longer to grow.

Magmas are chemically complex and don’t have a single freezing point. Typically they freeze to a variety of minerals over a range of ~150 to 250°C. For example, a slowly cooled basalt that started to crystallize at 1250°C would finally be completely solid at ~1000°C.

Once crystals form (GREEN) they tend to grow larger so long as the cooling magma remains hot and some liquid remains. Very slow cooling therefore tends to result in small numbers of large crystals.

If the cooling process results in some crystals forming, with little more cooling for a long time, small numbers of crystals can grow suspended in the liquid (right). When cooling begins again, the original crystals have a head start and will be larger than the rest when crystallization is complete. This produces porphyritic textures. The large crystals are called phenocrysts.
This is a set of photos of thin sections of basalt magmas. 1 to 6 are from Iceland lavas, and 7 is from Greenland. From 1 to 7 the time for cooling increased from seconds for 1 to over 1000 years for 7. All represent the same magma type, so the main difference between them is cooling rate.

Numbers 1, 2, and 3 are from a single lava pillow erupted onto the sea floor. Its rim (1) cooled very fast, but the nearby interior (2) probably took several minutes and the pillow center (3) probably took an hour or two to solidify. The increase in time for crystallization left a glass (obsidian) (1), mostly glass with huge numbers of very tiny crystals making the rock very dark (2), to mostly crystals (3) and little glass.

Numbers 4 and 5 are from a thin lava flow (~1 m) and a thick flow (~3 m), respectively. Both cooled in air and so took many hours to many days to crystallize. They are therefore coarser grained than any in the pillow lava.

Number 6 is from a lava lake or lava pond, where a layer of magma probably >20 m thick crystallized over months to perhaps over a year.

Number 7 is from the Skaergaard intrusion in east Greenland. It was not a lava flow or even a lava lake, but rather was a large mass of magma deep in the crust ~10 km long, ~7 km wide, and ~3 km thick, occupying a volume of ~180 km³. The thousands of years this large pluton took to crystallize permitted crystals to grow large.
This photo of Hawaiian lava flowing into the sea illustrates how water can quickly cool the lava flow. Under water, pillow lavas form and cool rapidly. This illustrates the situation for thin section photos 1, 2, and 3.
Basalt pillow lavas in a matrix of fragmented basalt lava. This was erupted in a glacial lake. Notice how the cracks in the pillows are generally radial from the center, following the direction of cooling.
This is a low-power view of a thin section through the pillow lava rim. It nicely shows the progression of crystallization from almost none on the left, where the rock is mostly a light brown glass, to considerable on the right, where the increasing amounts of dark material represent lots of tiny crystals that block the light. The olivine phenocrysts grew in the magma before eruption to the surface. The gas bubbles grow as water and CO$_2$ came out of solution from the magma at low pressure.
Thin section 1. Mostly glass at the pillow lava rim. Round things are gas bubbles, large angular thing on the left is an olivine phenocrysts. Dark objects in the glass are rapidly growing crystals.
Thin section 2. A few centimeters away from the rim, cooling rates were slow enough so lots of small crystals could grow. The round things are gas bubbles, and the angular thing at the upper left is an olivine phenocryst. The rest is a mass of brown glass and small crystals, some of which are large enough to see as white needles.
Thin section 3. This is from the center of the lava pillow, ~40 cm from the rim. Not much glass is left, and instead the matrix is made mostly of mats of feathery and needle-shaped crystals. Round objects are gas bubbles, as before, and the angular object in the bottom center is an olivine phenocryst.
This is an illustration of a thin lava flow. This is a Hawaii pahoehoe flow from Kilauea.
Thin section 4. This section was taken from a thin Iceland lava flow ~1 meter thick. It cooled in air so crystallization probably took place over many hours. Minerals are starting to be easily identifiable at this magnification: white is plagioclase feldspar, brownish-green is pyroxene, black is magnetite.
This is an illustration of a thick lava flow. It is an Aa flow from Kilauea in Hawaii.
Thin section 5. This sample was from an Iceland lava ~3 m thick, so it probably had at least days to crystallize, so the crystals are larger. Minerals are easily identifiable: white is plagioclase feldspar, brownish-green is pyroxene, black is magnetite.
Here is a lava lake on the Kilauea volcano, Hawaii. It illustrates a thick layer of ponded lava at the surface. These layers can exceed 100 meters in thickness and can take years to crystallize.
Thin section 6. This is from a thick ponded lava in Iceland. Its crystals are still larger than in previous images. Minerals are easily visible: white is plagioclase feldspar, brownish-green is pyroxene, black is magnetite.
The Skaergaard intrusion in east Greenland is a large blob of magma emplaced below the surface. It probably took over 10,000 years to completely crystallize, though the intrusion margins probably started crystallizing almost at once. The left view is unobstructed. The right view shows the intrusion outer margin in red. The basalt magma, now coarse-grained gabbro, is on the left side of the red line. The cool host rocks of the crust, into which the magma was intruded, is gray and on the right side of the contact. People in the foreground are for scale.

The Skaergaard intrusion is ~10 km long, ~7 km wide, and ~3 km thick, occupying an original magma volume of ~180 km³. The thousands of years this large pluton took to crystallize permitted crystals to grow large.
Thin section 7. This shows coarse-grained crystals of white plagioclase feldspar and grayish pyroxene from the lower part of the intrusion. Individual crystals are typically 10 mm long, and so are larger than the width of the photographs.
Thin section 8. This is a photograph of crystals of greenish pyroxene and black magnetite floating in a sea of light brown rhyolite glass. These crystals are therefore phenocrysts that grew from the liquid as it slowly crystallized below ground. The magma erupted to the surface and the liquid quickly cooled to a glass, resulting in this characteristic porphyritic texture.
Thin section 9, plane polarized light. This Iceland basalt lava sample has a matrix of small block- and needle-shaped crystals. Surrounded by this matrix are larger crystals of olivine. The olivines probably grew during slow cooling below ground, and the small crystals in the matrix grew during rapid cooling after eruption onto the surface. The result is a characteristic porphyritic texture with large crystals set in a finer-grained matrix.
Thin section 9, **cross polarized light**. Same as the previous thin section, but in cross polarized light the mineral interference colors make the some of the phenocryst crystals show up better.