How fast can crystals grow?

Geologists are known for looking at slow moving events that take vast amounts of time. Some geologic events, though, happen very rapidly - floods, volcanic explosions, asteroid impacts to name a few. It is also a truism that in looking at igneous rocks, those with larger crystals have crystallized more slowly than those which have smaller crystals. What is meant by “slowly” in these contexts? We can see lava flows cool rapidly. Dark glassy crusts form on them within seconds of eruption, and cool to the touch within days. When we look at the crystals in them they are generally very tiny, or in the case of volcanic glass, virtually non-existent. An exception is larger crystals brought up as passengers in the magma from below, where they presumably crystallized more slowly.

There are very coarse igneous rocks called pegmatites. These are often granite and mineral grains in them can be many feet long. Near Keystone, South Dakota, for example, one can see pegmatites with single spodumene crystals in them over 46 feet long. This tempts one to jump to the conclusion that the growth was quite slow, perhaps taking millions of years.

This is a misconception. Crystals can grow very fast given the right conditions. For example, large industrial quartz crystals can be grown in days in labs under controlled conditions. Good sized ice crystals can form on lakes or puddles overnight. And, apparently, giant crystals in pegmatites can grow astonishingly fast too.

A recent paper by geologists at the University of New Orleans (Webber, et. at. 1999) presents a detailed model for mineral crystallization in four pegmatites in California, including the Himalaya dike, famous for its large gem tourmalines. They gathered data on the temperature of the magma upon intrusion and the temperature of the surrounding rocks. They factored in such things as the rate of heat loss, thickness of the dike and the heat released as the crystals grew from the magma. Their calculations show that one pegmatite body 25 meters thick took around 9 years to crystallize, while the one meter thick Himalaya dike probably took about 5 days. This means that the largest gem tourmaline crystals of the Himalaya dike grew at about 4 cm. (about 2 inches) per day!

So how do the crystals get so big if they grow so fast? The compositions of pegmatites are such that they actually allow relatively few crystals to grow. The main culprit seems to be the presence of abundant water vapor, which retards the formation of crystal nuclei. Those crystals that are able to form will be able to grow large because they will have little competition for available chemicals. It's a bit like growing carrots in the yard. If the carrots are crowded together, you will get lots of carrots, but they'll mostly be tiny. If you thin and separate them, you'll get fewer but larger carrots. When a magma cools to the extent that it gets saturated or even supersaturated in a particular mineral, those few grains of that mineral that do form will grow big in a hurry. The water also helps in circulating chemicals through the magma to the sites where crystals are growing, helping them along.

If the magma suffers a pressure loss (cracked during an earthquake, let’s say), and the watery fraction escapes, a lot of crystals will nucleate and grow all at once, making a relatively fine-grained rock. We see evidence for this in lots of pegmatites, where zones in these coarse bodies grade over short distances to masses of small intergrown sugary-textured crystals called aplites.

While Webber et. al.'s models are specific to the California pegmatites, the principles they outline likely apply in general to many pegmatites, as well as other igneous rocks. The windows we have in the past show us only flashes of time in the earth's long history.

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References:

Webber, K; Simmons, W.; Falster, A; and Foord, E, 1999, “Cooling rates and crystallization dynamics of shallow level pegmatite-aplite dikes, San Diego County, California” American Mineralogist, vol. 84, p. 708-717.