Lecture 3  Igneous Textures

Monday, January 31st, 2005

Igneous Textures

The growth of a crystal in a melt depends on three factors:

- Initial nucleation of crystals
- Crystal growth
- Diffusion of chemical species in the melt

Most of these are dependent on cooling rate (or under-cooling. Consequently by studying textures we are learning something about how the magma cooled.

Additionally, we want to be able to deduce the sequence in which minerals formed.
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Figure 3-1. Idealized rates of crystal nucleation and growth as a function of temperature below the melting point. Slow cooling results in only minor undercooling ($T_a$), so that rapid growth and slow nucleation produce fewer coarse-grained crystals. Rapid cooling permits more undercooling ($T_b$), so that slower growth and rapid nucleation produce many fine-grained crystals. Very rapid cooling involves little if any nucleation or growth ($T_c$) producing a glass.

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Figure 3-2. Backscattered electron image of quenched “blue glassy pahoehoe,” 1996 Kalapana flow, Hawaii. Black minerals are felsic plagioclase and gray ones are mafics.

a. Large embayed olivine phenocryst with smaller plagioclase laths and clusters of feathery augite nucleating on plagioclase. Magnification ca. 400X.

b. ca. 2000X magnification of feathery quenched augite crystals nucleating on plagioclase (black) and growing in a dendritic form outward. Augite nucleates on plagioclase rather than pre-existing augite phenocrysts, perhaps due to local enrichment in mafic components as plagioclase depletes the adjacent liquid in Ca, Al, and Si. © John Winter and Prentice Hall.
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**Figure 3-3.** a. Volume of liquid (green) available to an edge or corner of a crystal is greater than for a side. **b.** Volume of liquid available to the narrow end of a slender crystal is even greater. After Shelley (1993). Igneous and Metamorphic Rocks Under the Microscope. © Chapman and Hall. London.

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**Figure 3-4.** a. Skeletal olivine phenocryst with rapid growth at edges enveloping melt at ends. Taupo, N.Z. **b.** “Swallow-tail” plagioclase in trachyte, Remarkable Dike, N.Z. Length of both fields ca. 0.2 mm. From Shelley (1993). Igneous and Metamorphic Rocks Under the Microscope. © Chapman and Hall. London.
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Figure 3-5. a. Compositionally zoned hornblende phenocryst with pronounced color variation visible in plane-polarized light. Field width 1 mm. b. Zoned plagioclase twinned on the carlsbad law. Andesite, Crater Lake, OR. Field width 0.3 mm. © John Winter and Prentice Hall.

Figure 3-7. Euhedral early pyroxene with late interstitial plagioclase (horizontal twins). Stillwater complex, Montana. Field width 5 mm. © John Winter and Prentice Hall.

Figure 3-8. Ophitic texture. A single pyroxene envelops several well-developed plagioclase laths. Width 1 mm. Skaergård intrusion, E. Greenland. © John Winter and Prentice Hall.
Figure 3-9. a. Granophyric quartz-alkali feldspar intergrowth at the margin of a 1-cm dike. Golden Horn granite, WA. Width 1mm. b. Graphic texture: a single crystal of cuneiform quartz (darker) intergrown with alkali feldspar (lighter). Laramie Range, WY. © John Winter and Prentice Hall.

Figure 3-10. Olivine mantled by orthopyroxene in (a) plane-polarized light and (b) crossed nicols, in which olivine is extinct and the pyroxenes stand out clearly. Basaltic andesite, Mt. McLaughlin, Oregon. Width ~ 5 mm. © John Winter and Prentice Hall.
Figure 3-11. a. Sieve texture in a cumulophyric cluster of plagioclase phenocrysts. Note the later non-sieve rim on the cluster. Andesite, Mt. McLoughlin, OR. Width 1 mm. © John Winter and Prentice Hall.

Figure 3-11. b. Resorbed and embayed olivine phenocryst. Width 0.3 mm. © John Winter and Prentice Hall.
Figure 3-11. c. Hornblende phenocryst dehydrating to Fe-oxides plus pyroxene due to pressure release upon eruption, andesite. Crater Lake, OR. Width 1 mm. © John Winter and Prentice Hall.

Figure 3-12. a. Trachytic texture in which microphenocrysts of plagioclase are aligned due to flow. Note flow around phenocryst (P). Trachyte, Germany. Width 1 mm. From MacKenzie et al. (1982). © John Winter and Prentice Hall.

Figure 3-12. b. Felty or pilotaxitic texture in which the microphenocrysts are randomly oriented. Basaltic andesite, Mt. McLaughlin, OR. Width 7 mm. © John Winter and Prentice Hall.
Figure 3-13. Flow banding in andesite. Mt. Rainier, WA. © John Winter and Prentice Hall.

Figure 3-15. Intergranular texture in basalt. Columbia River Basalt Group, Washington. Width 1 mm. © John Winter and Prentice Hall.

Figure 3-14. Development of cumulate textures. a. Crystals accumulate by crystal settling or simply form in place near the margins of the magma chamber. In this case plagioclase crystals (white) accumulate in mutual contact, and an intercumulus liquid (pink) fills the interstices. b. Orthocumulate: intercumulus liquid crystallizes to form additional plagioclase rims plus other phases in the interstitial volume (colored). There is little or no exchange between the intercumulus liquid and the main chamber. After Wager and Brown (1967), Layered Igneous Rocks. © Freeman. San Francisco.
Figure 3-14. Development of cumulate textures. 

**c. Adcumulates:** open-system exchange between the intercumulus liquid and the main chamber (plus compaction of the cumulate pile) allows components that would otherwise create additional intercumulus minerals to escape, and plagioclase fills most of the available space.

**d. Heteradcumulate:** intercumulus liquid crystallizes to additional plagioclase rims, plus other large minerals (hatched and shaded) that nucleate poorly and poikilitically envelop the plagioclases. After Wager and Brown (1967), *Layered Igneous Rocks*. © Freeman. San Francisco.

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**Figure 3-16. a.** The interstitial liquid (red) between bubbles in pumice (left) become 3-pointed-star-shaped glass shards in ash containing pulverized pumice. If they are sufficiently warm (when pulverized or after accumulation of the ash) the shards may deform and fold to contorted shapes, as seen on the right and **b.** in the photomicrograph of the Rattlesnake ignimbrite, SE Oregon. Width 1 mm. © John Winter.
Primary Twins

Figure 3-18. a. Carlsbad twin in orthoclase. Wispy perthitic exsolution is also evident. Granite, St. Cloud MN. Field widths ~1 mm. © John Winter and Prentice Hall.

Primary Twins

Figure 3-18. b. Very straight multiple albite twins in plagioclase, set in felsitic groundmass. Rhyolite, Chaffee, CO. Field widths ~1 mm. © John Winter and Prentice Hall.

Secondary Twinning

Figure 3-18. (c-d) Tartan twins in microcline. Field widths ~1 mm. © John Winter and Prentice Hall.
Figure 3-19. Polysynthetic deformation twins in plagioclase. Note how they concentrate in areas of deformation, such as at the maximum curvature of the bent cleavages, and taper away toward undeformed areas. Gabbro, Wollaston, Ontario. Width 1 mm. © John Winter and Prentice Hall.

Figure 3-20. a. Pyroxene largely replaced by hornblende. Some pyroxene remains as light areas (Pyx) in the hornblende core. Width 1 mm. b. Chlorite (green) replaces biotite (dark brown) at the rim and along cleavages. Tonalite. San Diego, CA. Width 0.3 mm. © John Winter and Prentice Hall.

**Autometamorphism**

*(Deuteric Alteration)*
Figure 3-21. Myrmekite formed in plagioclase at the boundary with K-feldspar. Photographs courtesy © L. Collins. http://www.csun.edu/~vegeo005