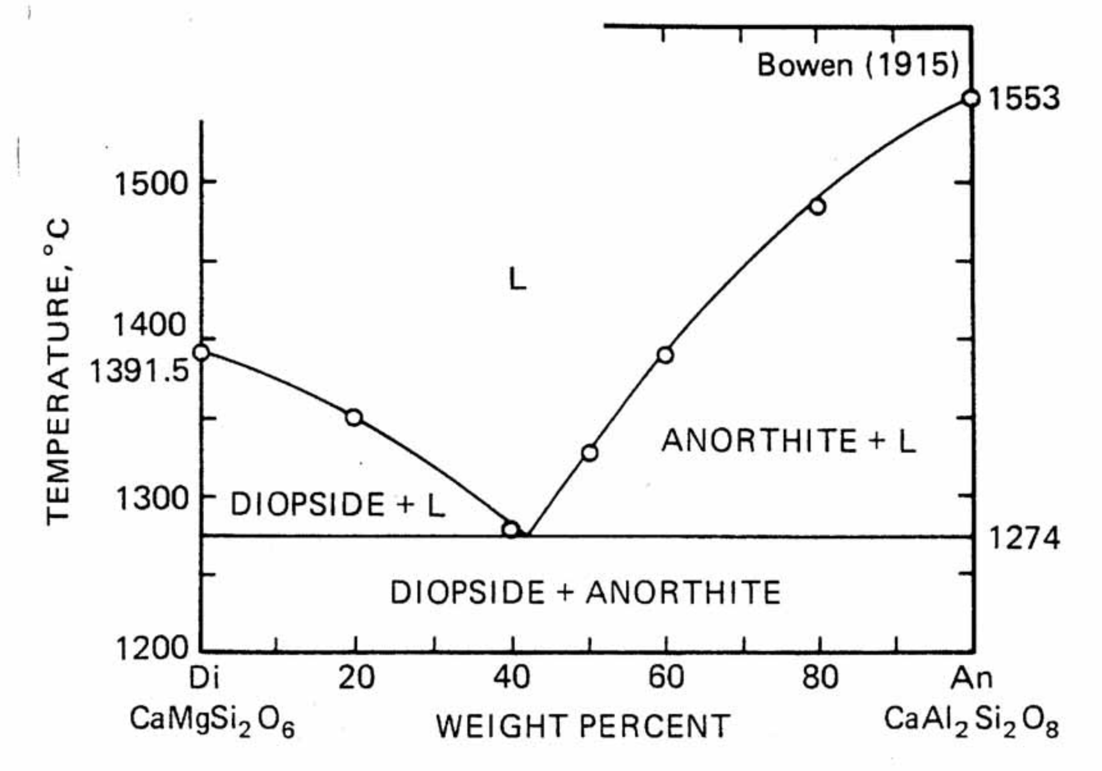
# Announcements

- Reading: none!
- Tents and food groups at the end

# Di-An binary



Bowen (1915)
1553
1500
1400
1391.5
1300
1200
1274
TEMPERATURE, °C
L
ANORTHITE + L
DIOPSIDE + L
DIOPSIDE + ANORTHITE
Di
20
40
60
80
An
CaMgSi2O6
WEIGHT PERCENT
CaAl2Si2O8

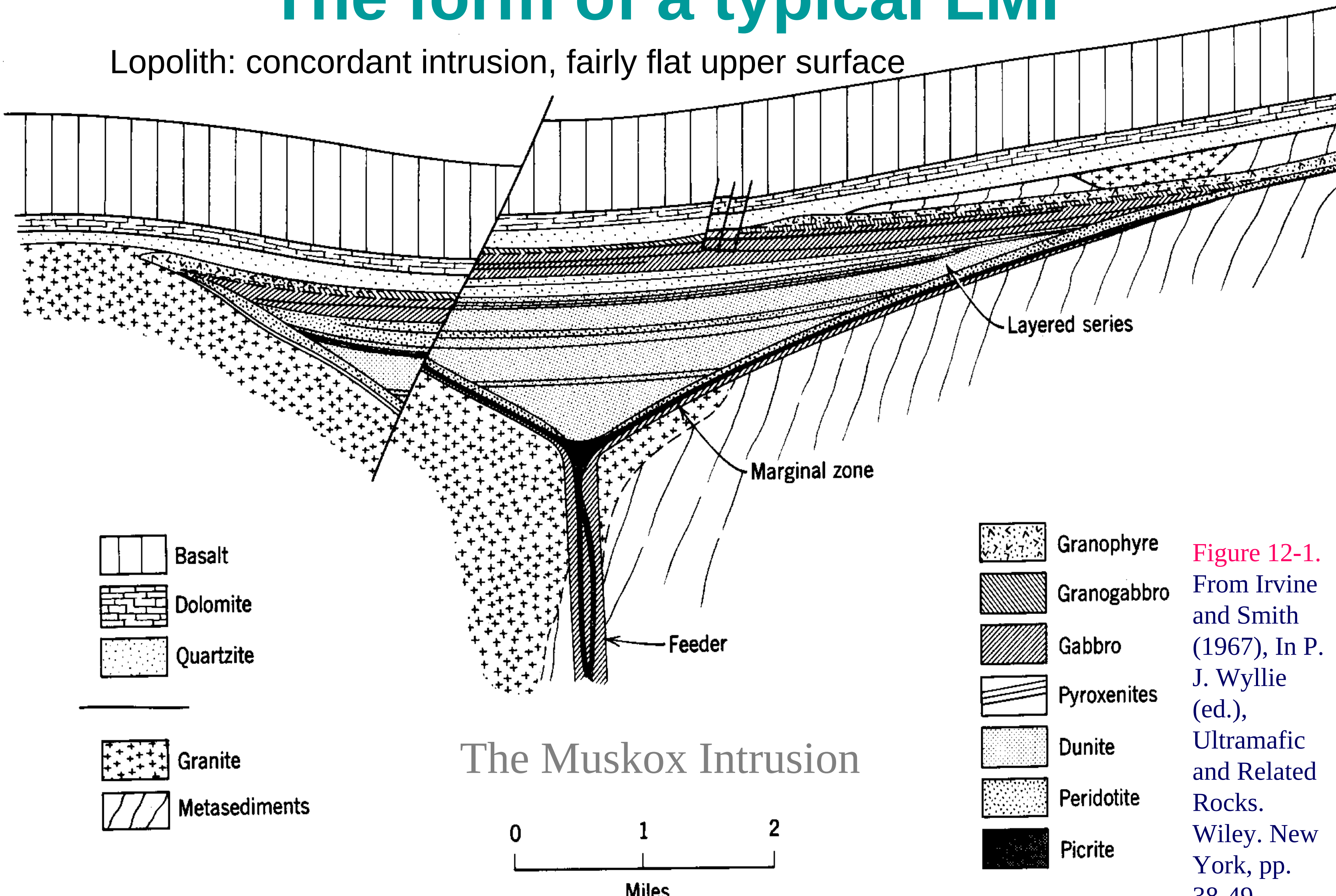

# Layered Mafic Intrusions: crystallization and differentiation

| **Name** | **Age** | **Location** | **Area** (km$^2$) |
|---|---|---|---|
| **Bushveld** | **Precambrian** | **S. Africa** | **66,000** |
| **Dufek** | **Jurassic** | **Antarctica** | **50,000** |
| **Duluth** | **Precambrian** | **Minnesota, USA** | **4,700** |
| **Stillwater** | **Precambrian** | **Montana, USA** | **4,400** |
| **Muskox** | **Precambrian** | **NW Terr. Canada** | **3,500** |
| **Great Dike** | **Precambrian** | **Zimbabwe** | **3,300** |
| **Kiglapait** | **Precambrian** | **Labrador** | **560** |
| **Skaergård** | **Eocene** | **East Greenland** | **100** |

exposed in continents, many associated with flood basalts, generally Precambrian

# The form of a typical LMI

Lopolith: concordant intrusion, fairly flat upper surface




The Muskox Intrusion

Figure 12-1. From Irvine and Smith (1967), In P. J. Wyllie (ed.), Ultramafic and Related Rocks. Wiley. New York, pp. 38-49.

# Cumulate textures

- Caution! texture vs. paragenesis

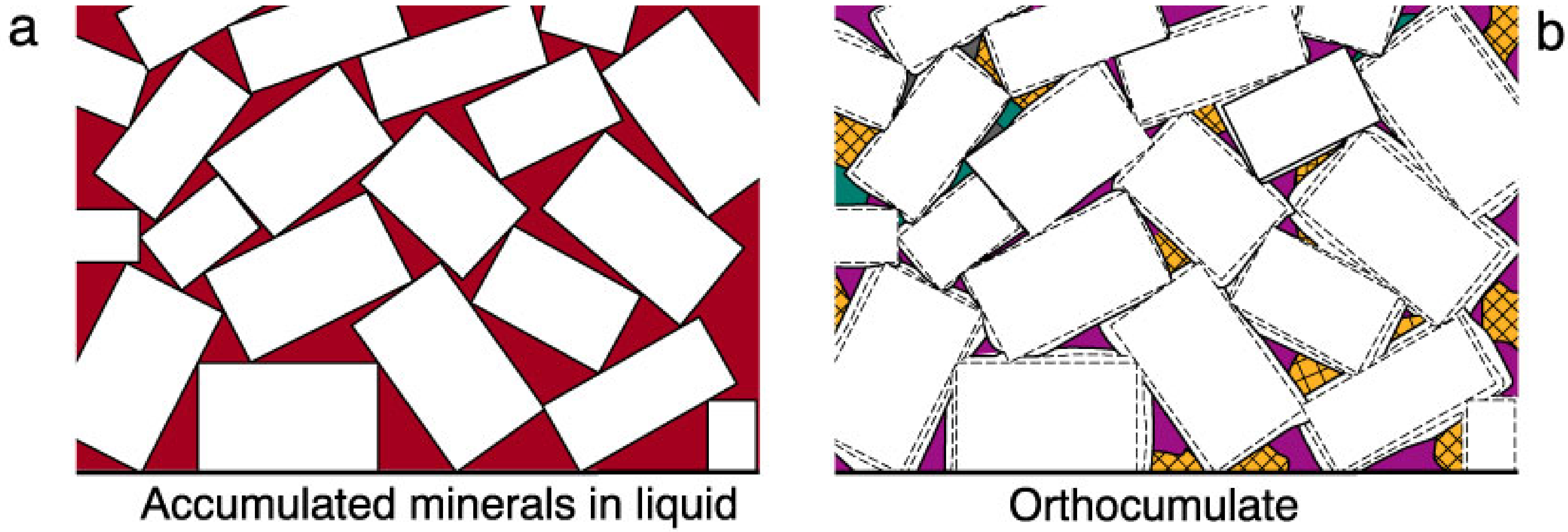
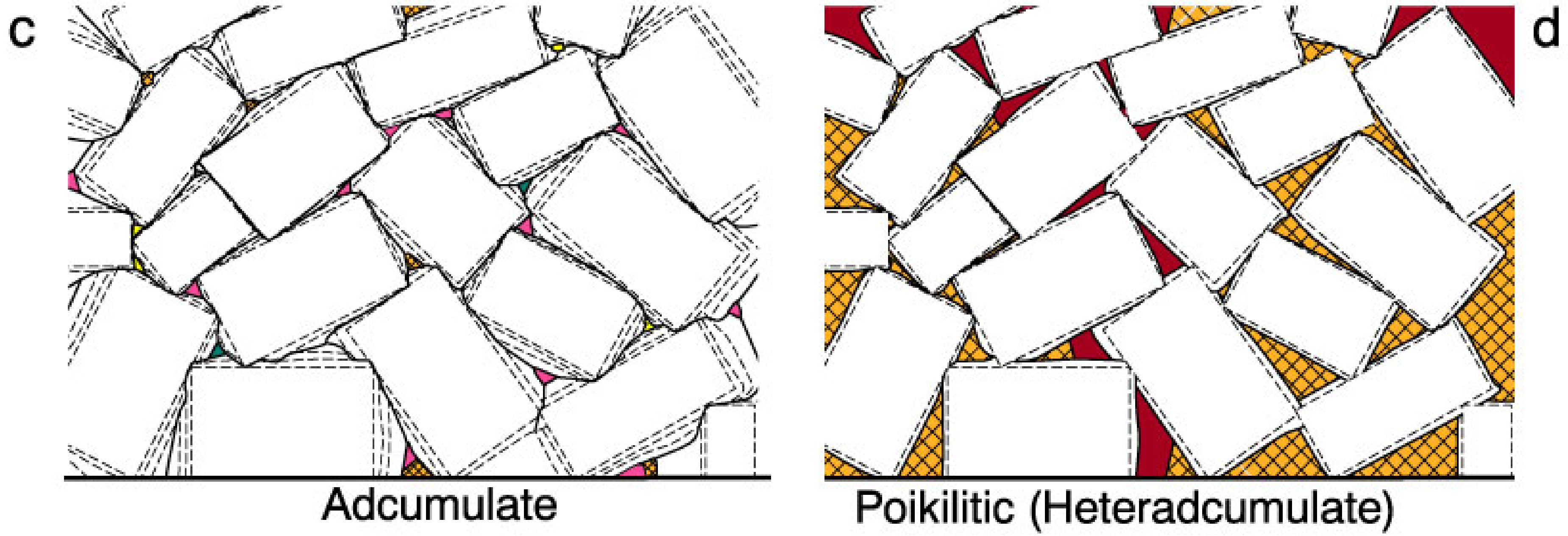



Figure 3-14. Development of cumulate textures. **a.** Crystals accumulate by crystal settling or simply form in place near the margins of the magma chamber. In this case plagioclase crystals (white) accumulate in mutual contact, and an intercumulus liquid (pink) fills the interstices. **b.** Orthocumulate: 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.

# Cumulate textures




Di-An phase diagram?

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.

# Layering

layer: any sheet-like cumulate unit distinguished by its compositional and/or textural features

- uniform mineralogically and texturally homogeneous
- non-uniform vary either along or across the layering
  - graded = gradual variation in either
    - mineralogy
    - grain size - quite rare in gabbroic LMIs

# Uniform Layering

**Uniform chromite layers alternate with plagioclase-rich layers, Bushveld Complex, S. Africa.**

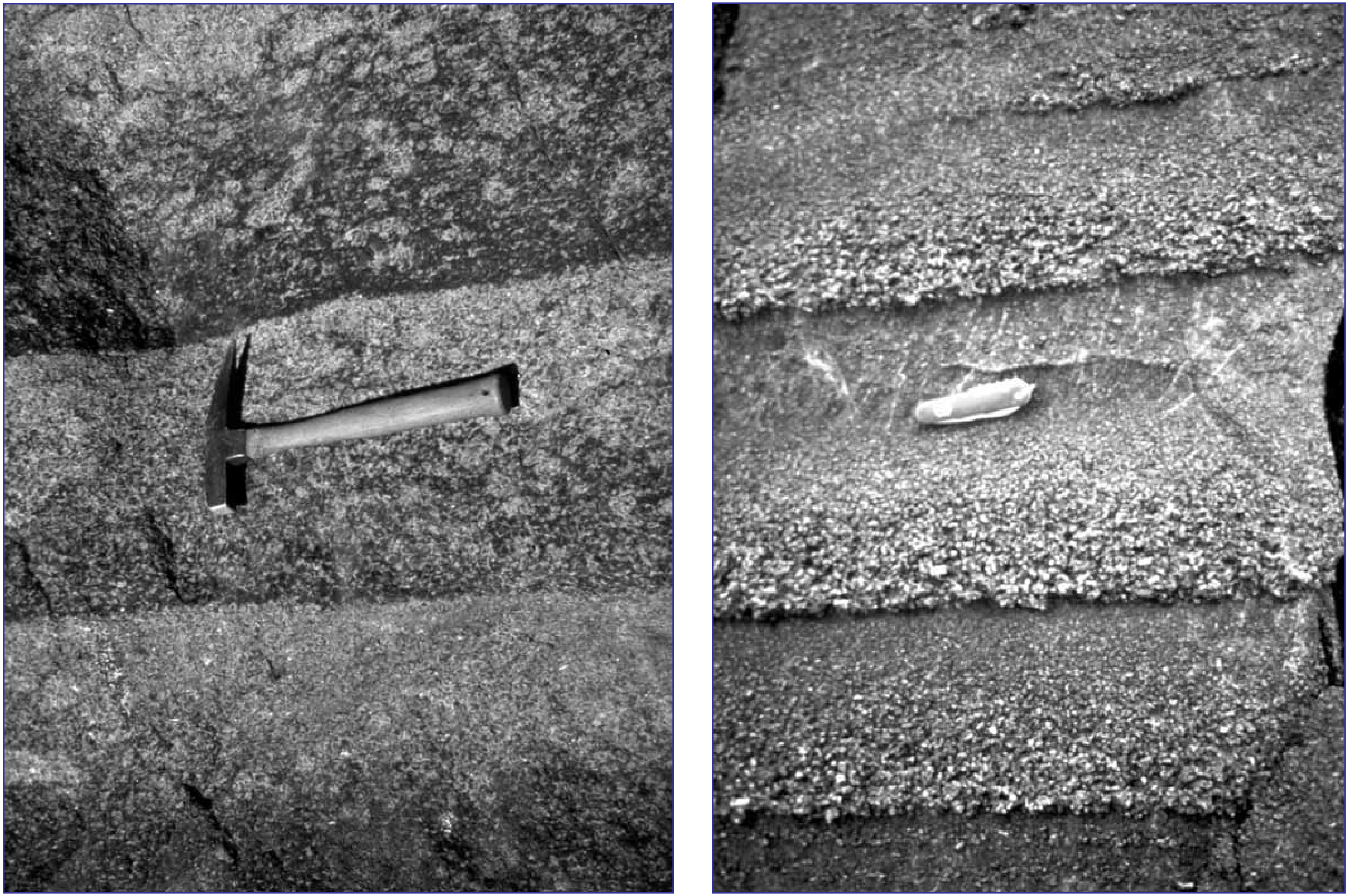
# Economic value of layered intrusions

4-10 g/t

Pt $881/ oz  Au $439 / oz

# Graded Layers

**Figure 12-2.** **Modal and size graded layers. From McBirney and Noyes (1979) J. Petrol., 20, 487-554.**



# Possible causes of rhythmic modal layering

- Periodic large-scale convective overturn of the entire cooling unit
- Reinjection of more primitive magma
- In situ crystallization
- Density currents along walls and floor

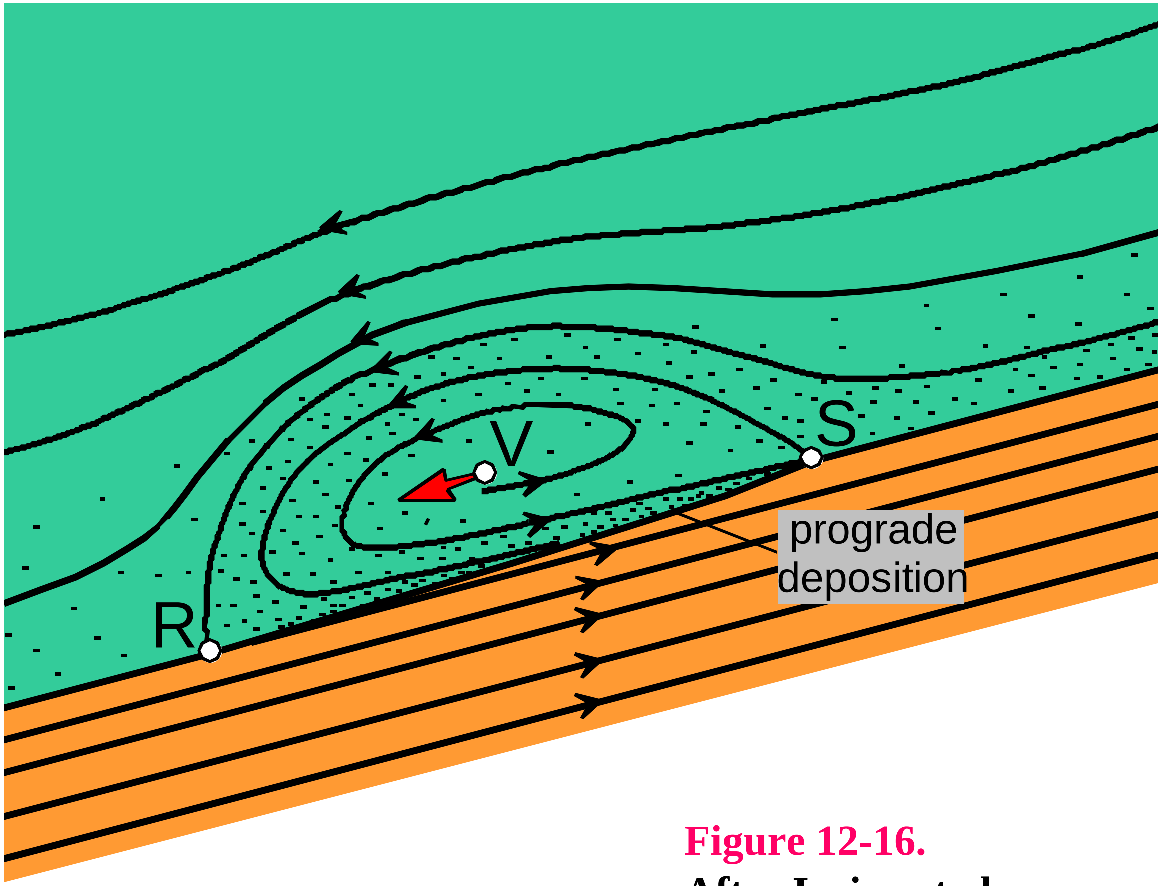
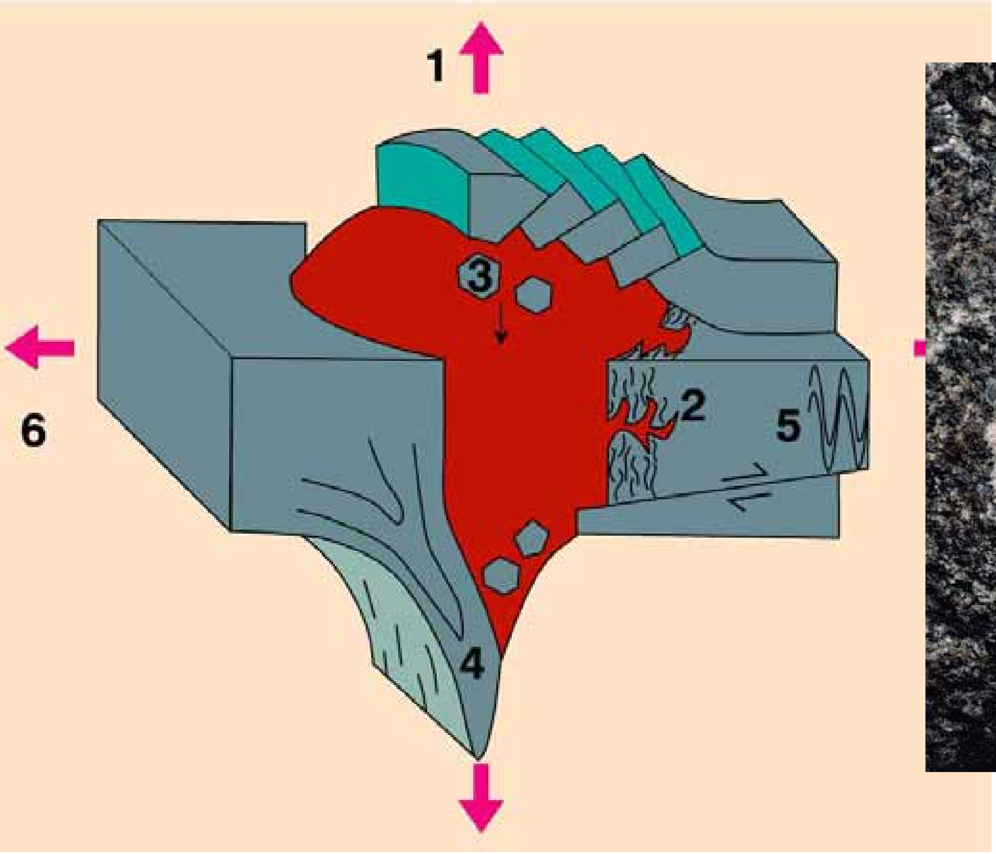



**Figure 12-16.** **After Irvine et al. (1998) Geol. Soc. Amer. Bull., 110, 1398-1447.**

# The Room Problem: Assimilation




# Melting on a phase diagram

- How does the melt composition/solid composition evolve?